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NEW RAPID SAND FILTER PLANT, WASHINGTON, D. C.

By Philip O. Macqueen[1]

Washington, D. C., is exceptionally fortunate among the larger cities of the United States in having an abundant and excellent supply of water, not only near the city but at an elevation of over 100 feet above its business section. The combination of these four water supply assets is quite unusual. Other large cities such as Chicago and Cleveland on the Great Lakes, St. Louis and New Orleans on the Mississippi River and Philadelphia on the Delaware have plenty of water, but they have sewage disposal and high pumping costs to contend with. New York and Los Angeles have aqueducts over 100 miles long. The water supplies of Baltimore and Boston are not far from the cities but the amounts available are far from being abundant. Washington, however, has an unlimited supply of relatively pure water only 9 miles from the city limits, and moreover the intake at this point is at the head of a series of falls and rapids in the river, so that a large part of the city can easily be supplied by gravity. This situation comes very close to being ideal so far as water supply is concerned.

The Potomac River, which is the source of supply for the city, is one of the principal streams in the eastern part of the United States, ranking just below the Hudson and Connecticut Rivers in point of size. The area of its watershed above the intake of the aqueduct is

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11,050 square miles, its total length is 450 miles and its average discharge is 11,900 cubic feet per second or 8,000 million gallons per day. In appearance the water is as a rule quite muddy, but the turbidity is not by any means as high as that of the Ohio River. This small amount of mud is easy to filter out and in some cases is a help rather than a hindrance, as it promotes rapid sedimentation with aluminum sulphate. The population on the watershed is relatively small and for a distance of 30 or 40 miles above the intake the urban population consists chiefly of small farms. Frederick, Maryland, the nearest large town is 45 miles above the intake on a branch of the river. This means that Washington is free from any decided pollution of its source of water supply.

Table 1 is given in order to show in a general way the character of the water.

TABLE 1

Potomac River water—average analysis

ITEM	RAW WATER	SETTLED WATER	FILTERED WATER
Maximum turbidity, p.p.m.	6000	1200	2
Average turbidity, p.p.m.	140	70	0.25
Hardness, p.p.m.	72	72	72
Chlorine, p.p.m.	3.7	3.7	3.5
Bacteria per cc. (average, 37°C. agar)	2500	100	2
Bacterium colon per cc. (average)	7	0.3	0.002
Average pH value	7.6	7.6	7.3

Construction of the first or old water system of Washington was begun about seventy years ago. The principal features consist of an aqueduct 11 miles long, a tunnel 4 miles long under the city, 3 large storage or settling reservoirs and two high service reservoirs, an 80 million gallon per day slow sand filter plant, a large steam operated pumping station and the distribution mains. A low over-flow dam 2800 feet long across the river at the head of the falls is provided at the intake of the aqueduct in order to have the conduit flowing full even when the river is low. The slow sand filter plant, built about twenty years ago, is one of the model plants of the country and is giving splendid service. A full description of this plant is given in Vol. 57 of the Transactions of the American Society of Civil Engineers, by its designing engineers E. D. Hardy and Allen Hazen. All structures except the pumping station and distribution mains (which are under the jurisdiction of the District of Columbia) were

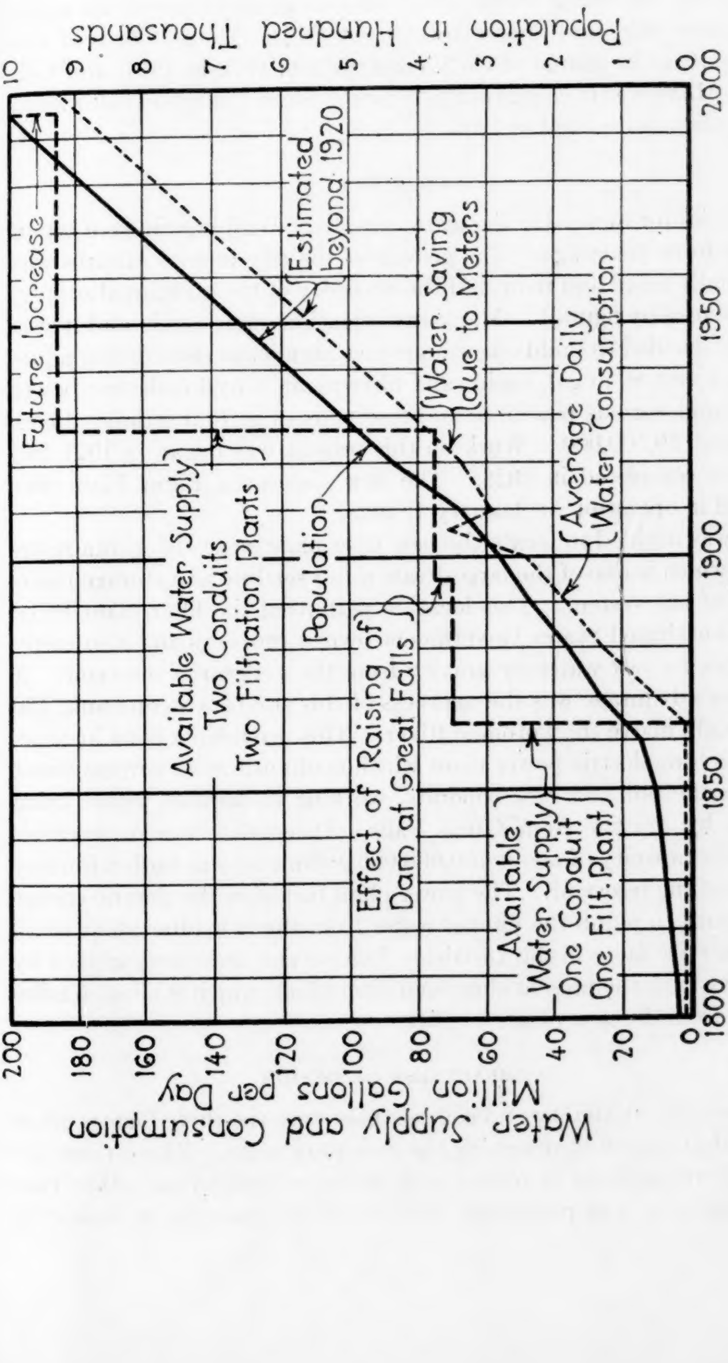

FIG. 1. POPULATION AND WATER CONSUMPTION CURVES FOR THE DISTRICT OF COLUMBIA

constructed by the War Department, Office of the Chief of Engineers, which also has charge of the operation and maintenance of the aqueduct, reservoirs and filter plant. Capt. M. C. Meigs, Corps of Engineers, was in charge of early construction work in 1854, and Col. A. M. Miller was in charge of the construction of the present slow sand filter plant completed in 1905.

NEW SUPPLY

Studies for increasing the water supply of Washington were begun about forty years ago. The growth of the city and its suburbs was unusually rapid and indicated the necessity of the additional supply, as is shown by figure 1. Many investigations were made and it was finally decided to build a new aqueduct parallel to the existing aqueduct, a new 80 m.g.d. rapid sand filter plant, a hydro-electric power plant and various pipe lines and reservoirs at a total estimated cost of about $9,500,000. Work on this project was begun in 1921 and will be completed in 1928. The new Dalecarlia Filter Plant was placed in operation on January 1, 1928.

It was decided to locate the new filter plant near Dalecarlia reservoir, which is one of the largest raw water settling and storage reservoirs of the system. This location permitted the filter plant to be built on United States Government owned property and also easily to draw its raw water by gravity from the Dalecarlia reservoir. A further advantage was the nearness of this site to a steep bank, 150 feet high, above the Potomac River. This provided a good location for a hydro-electric power plant which could utilize all surplus water which the old and new conduits, working in parallel, could bring down by gravity from Great Falls. Dalecarlia storage reservoir with its capacity of about 100,000,000 gallons acts as both a forebay and settling reservoir. The power plant furnishes the electric energy necessary to pump the filtered water from the new filter plant to all high service areas in the District. Low service areas are supplied by gravity from the present slow sand filter plant, which is about 6 miles away from the new plant.

COMPACTNESS OF DESIGN

Economy, flexibility and compactness were the three factors given special attention in designing the new filter plant. These three are closely related and in reality each is engendered by the other two. Compactness was practically forced into the question of design by

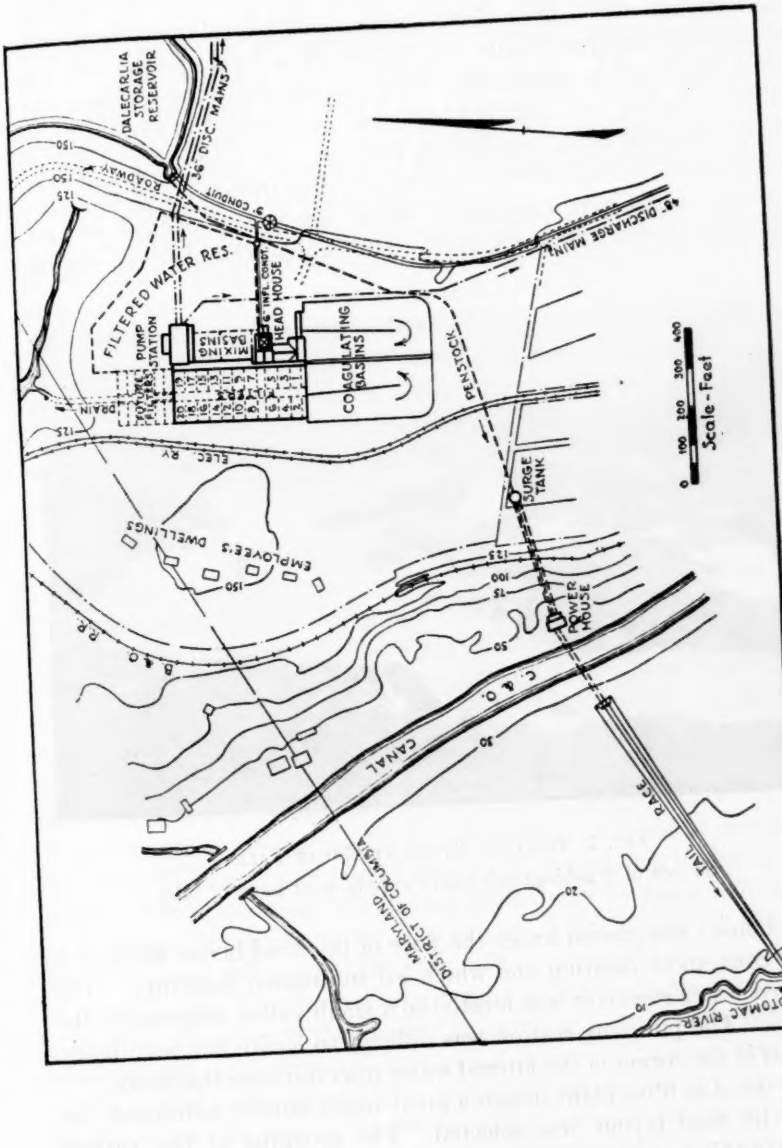

FIG. 2. NEW FILTRATION PLANT, WASHINGTON, D. C.

topographic conditions. The United States owned a large area of land around Dalecarlia reservoir, but only about 10 acres of this was level enough for a filter plant layout. This level tract, as shown in figure 2, was practically cut in two by a local electric car line which could not be eliminated. The best answer to the problem was to move the car line slightly to one side and group the various units of the plant as close together as possible. An unusually compact layout and also considerable economy resulted from this arrangement. Separate walls were eliminated, water passages shortened and all buildings placed under one roof. The control chamber (or central

FIG. 3. POTOMAC RIVER AT GREAT FALLS
Source of Washington's water supply is at head of falls

gate house) was placed under the floor of the head house which is a very convenient location and which led to unusual flexibility. The filtered water reservoir was located in a small valley adjacent to the filters. The pumping station was difficult to locate but was finally placed in the corner of the filtered water reservoir near the filters.

As usual in filter plant design a great many studies were made before the final layout was selected. The grouping of the various units in this case is not all that could be desired, but it was the best obtainable under local conditions.

A careful sub-soil survey of the entire area of the filter plant was made by dividing the area into 50-foot squares and taking wash borings from 10 to 30 feet in depth at each intersection. These results were plotted and formed a part of the contract drawings. In general it was determined that the various structures would rest on either solid red or yellow clay or a mixture of clay and rock. The borings indicated that hard rock would be from 10 to 20 feet below the lowest principal foundations and would be encountered in only a few places. Total earth and rock excavations for the plant amounted to about 110,000 and 1,000 cubic yards, respectively.

It was decided from investigation that the solid clay was capable of sustaining a load of 2 tons per square foot and this figure was not exceeded in the designs. The heaviest load in the construction was the head house tower, which is 150 feet high and contains the large chemical storage bins. The weight of this part of the structure is approximately 3000 tons, and it is supported on a heavily reinforced concrete mat 49 feet square and 4 feet thick. As the site of the plant is 150 feet above the Potomac River the soil in general was well drained and very little trouble was experienced with ground water.

CHEMICAL TREATMENT AT INFLUENT

The raw water supply for the filter plant flows by gravity from the Dalecarlia storage reservoir about 600 feet away, enters the plant through a 6-foot diameter concrete conduit, and passes first through the control chamber. This structure is a compact series of sluice gates and intersecting water passages located near the central point of the filter plant, and it is similar in a general way to the cross-connection gate houses found in large filter plants. Treated water, settled water and filtered water all pass through separate passages of the control chamber, thus providing the limit of flexibility. In case of necessity the treated water may be passed directly to the settling basins or the filters. The water from the mixing basins may be passed directly to the filters or the raw water may be passed directly to the filtered water reservoir and pumping station. The necessity of such extremes in operation are of course remote, but by no means impossible.

Another function of the control chamber is to provide a central point for the application of alum and chlorine. The alum solution can be applied to the water before and after passage through the mixing chambers and also to the settled water before it passes through the filters, or if desired the dose can be divided so that a small extra

charge of alum can be added to the water at any stage. This flexibility is expected to be of value in obtaining the best results in the process of coagulation, but it has not been used as yet. It has been found by experience that the alum is much more efficient when added at the influent gate chamber about 300 feet before the raw water enters the plant. Four-inch fibre ducts embedded in concrete are used in transporting the alum liquid outside the building and cast iron pipe is used inside the building.

MIXING CHAMBERS

After the alum is applied to the raw water it flows to the two mixing basins. These basins, 80 feet square and 18 feet in depth, are fitted with baffles of the "around the end" type, which are used for thoroughly combining the chemicals with the raw water. The baffles are constructed of $\frac{7}{8}$ inch tongue and groove Georgia pine lumber, braced throughout with 4 inch by 4 inch struts, so as to support the thrust due to the maximum loss of head. Each basin contains 20 passages 4 feet wide and 80 feet long, making a total travel of 1600 feet per basin. Provision is made for using the basins either in series or in parallel, and further flexibility of operation is provided by an extra effluent gate near the half-way flow point in each basin.

With the basins operating in series mixing periods of eight, fourteen, nineteen and twenty-seven minutes, with a velocity of 2 feet per second can be obtained with a flow of 80,000,000 gallons per day. With the basins in parallel and the same flow the mixing periods can be made fourteen or twenty-seven minutes, with a velocity of 1 foot per second. The observed loss of head under the latter condition is about $2\frac{1}{2}$ feet. With flows of 60,000,000 or 40,000,000 gallons per day mixing periods will be lengthened and losses of head decreased.

Experimental work with mixing basins is always advisable where possible when a new filter plant is being tuned up, and long and short mixing periods are used until the best working conditions are found. As shown by the above figures the range of operation of the mixing basins will be wide enough to get the best results and also meet changes which are constantly occurring in the raw water. As a rule it is easy to start an argument among water works men on the merits or defects of the "around the end" type of baffles. In the case of Washington it was the desire to operate with the smallest loss of head possible and to have the water level in the mixing basins, settling basins and filters rise and fall in parallel with corresponding

changes of level in the Dalecarlia raw water storage reservoir. Under these conditions "around the end" baffles were practically required.

The writer is much interested in the various new mixing methods which are now being tried out in other filter plants. Unusual economy has been obtained in many cases by adding the chemicals at the suction end of the low lift centrifugal pumps. Perhaps the most violent mixing, however, is now being used in Panama where the chemicals are passed through the aerating system. In this last case filter runs were doubled, the volume of wash water was reduced 50 per cent, and a very considerable saving was made in the use of chemicals. Another example of violent mixing is found in the use of the hydraulic jump in the new filter plants at Cleveland and Bay City, Michigan. The question of proper mixing is one of the most important problems which filter engineers have to solve. The first cost of the mixing system is undoubtedly important but by no means the most important.

In adding alum to the raw water for the slow sand filter plant at Washington no mixing basins whatever are used. The treated water flows in almost a direct line for a distance of about 2 miles at a velocity of 1 foot per second, through a conduit 9 feet in diameter, and then enters the Georgetown settling reservoir. The mixing action in this case takes place in about three hours and is apparently fully as efficient as that which occurs in the Dalecarlia mixing basins with their baffled passes.

SETTLING BASINS

From the mixing basins the water flows through a 5 foot by 9 foot concrete duct, about 200 feet long, to the coagulating or settling basins located at the south side of the filter plant. These two basins are open concrete structures 333 feet long, 150 feet wide and from 17 to 12 feet deep. They are separated by a substantial concrete dividing wall. Each basin is provided with a light concrete baffle wall which causes the water to travel the full length of the basin and then return to a point opposite the influent. The baffle wall is constructed on an angle of about 5 degrees toward the center dividing wall which tends to cause the water to move more slowly at the halfway and end points of its flow in the basin. Experiments made at Baltimore indicate that this arrangement will facilitate sedimentation. Water enters the basins at one end near the bottom through 4

sluice gates 48-inch square and is then deflected upward with wooden baffles. Five sluice gates of the same size, but at a higher level are provided for the effluent.

When the basins are operating in parallel, which will be the normal condition, and the flow is 80,000,000 gallons per day, the settling period is approximately three hours and the velocity of the flow is 3 feet per minute. With a flow of 40,000,000 gallons per day, which will be used for about the first ten years of operation, the settling period will be about six hours and the velocity $1\frac{1}{2}$ feet per minute. The sedimentation periods may be shortened if desired by passing the water through the dividing wall which is constructed with a hollow core.

The floors of the basins have slopes of 10:1 to facilitate cleaning. Water pressure lines with $2\frac{1}{2}$ inch hose connections are provided at suitable intervals for washing, and also an 18-inch low pressure flushing line with 10-inch gate valve outlets 50 feet apart. One basin can be cleaned while the other is in service, thus avoiding shutting down the plant. The cleaning of one basin can be done in three hours with 8 men.

FILTER BUILDING

The filter building is 361 feet long and 155 feet wide, and contains 20 filters arranged in two parallel rows of 10 each, separated by a central pipe gallery. Each filter is a rectangular concrete structure 54 feet long, 31 feet wide and 15 feet deep, with a net sand area of 1477 square feet. Using the rates of filtration of 125 and 150 million gallons per acre per day, the filter capacities are 4,238,000 and 5,086,000 gallons per filter per day, respectively. The filters are considered as 4,000,000 gallons per day units, but it is recognized that 5 m.g.d., or even 6 m.g.d., is not by any means excessive, and controllers, piping and equipment have been designed with this in view. Taking into consideration filters out of service and wash water demands the maximum net output of the plant may be safely taken as 80,000,000 gallons per day. Each filter is equiped with a 20-inch Simplex rate controller and five Renssalaer hydraulically operated gate valves. The filter operating tables furnished by the American Water Softening Company are made of green slate with a brass grill at the front and sides. They present a particularly pleasing appearance.

The filter strainer system is of the open wooden slat type similar

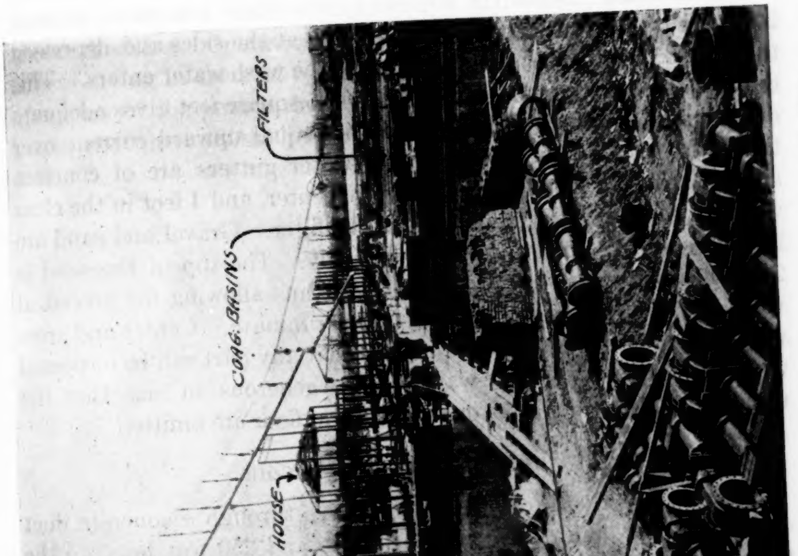

FIG. 4. GENERAL VIEW OF NEW FILTRATION PLANT UNDER CONSTRUCTION, APRIL 2, 1926

to that installed in the new Baltimore plant. The slats are 1 inch by 10 inches yellow pine, spaced so as to allow openings of 1 inch between the slats. Below the strainer system there is a water passage 24 inches deep in the center, 6 inches deep at the sides and depressed to a depth of 50 inches at the end where the wash water enters. This cross-sectional area amounting to about 35 square feet gives adequate opportunity for wash water to exert an equal upward current over the entire area of the filter. Wash water gutters are of concrete and are spaced 6 feet 9 inches center to center, and 4 feet in the clear with the main gutters on one side of the filter. Gravel and sand are 20 inches and 24 inches deep, respectively. The top of the sand is 22 inches below the top of the gutters, thus allowing for a vertical velocity of wash water of about 2 feet per minute. Center and cross walks are provided on the filter tops so that any part can be inspected with perfect ease. These walks are so generous in size that the usual railing between filter tops and central floor are omitted.

FILTERED WATER RESERVOIR

After leaving the filters the water passes through a concrete duct 4 feet 9 inches high, 9 feet 6 inches wide and 250 feet long, to the filtered water reservoir, which is located on the northeast side of the plant. The reservoir is a covered concrete structure with a storage capacity of 15,000,000 gallons, acting as a local balancing factor between the filters and pumps.

The shape of the reservoir is quite irregular with a maximum length and width of about 400 feet, and an average depth of 20 feet. Outside walls were built to follow the contours so as to avoid as far as possible any construction of filled ground. The roof is of the flat slab type, 9 inches thick, with a four-way system of reinforcement. Columns are circular in shape, 24 inches in diameter and spaced 16 feet 6 inches center to center. Side walls are constructed with a heavy gravity section and the floor is of the inverted groined arch type, 6 inches thick at the low point and 18 inches thick under the columns. Floor joints are sealed with 6 inch by 24 inch concrete blocks with the top surfaces and vertical joints coated with plastic cement.

The reservoir operates on a somewhat different principle than the average filtered water reservoir. The maximum flow line is on a level with the tops of the filters so that when the reservoir is full the filters automatically cease to operate. As the water level in the

reservoir drops the filters begin to operate and gradually attain a maximum capacity when the reservoir drops down to or below the level of the filtered water effluent weir, which acts as a water seal for the controllers. Operation of the reservoir in this way not only effects saving in the cost of pumping, but tends to simplify the joint operation of the pumps and the filters, as, if the pumps are slowed down, the water in the reservoir rises and forces the filters to slow down.

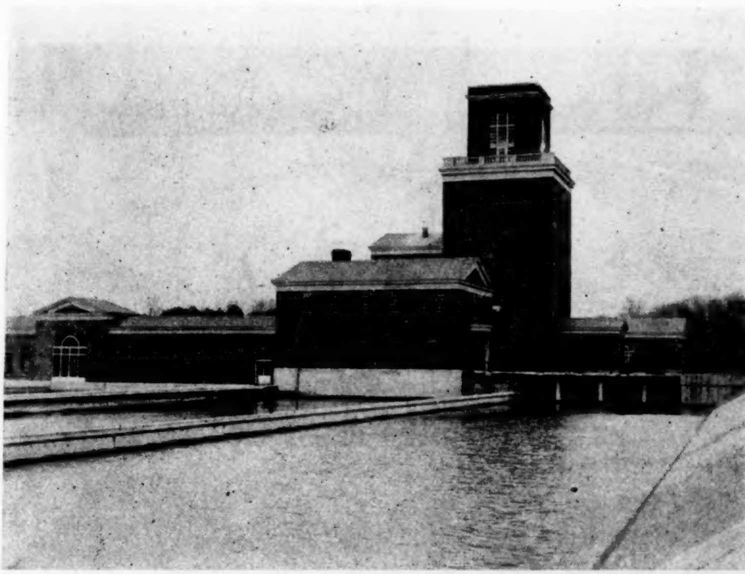

FIG. 5. VIEW OF BUILDINGS FROM END OF SETTLING BASINS

The capacity of the reservoir below the water seal of the controllers is only about 50 per cent of the full capacity. Washington, however, has four other large filtered water reservoirs in other parts of the city and the decreased capacity of the reservoir at the plant is not a material loss to the general filtered water storage system. Smaller cities with a single filtered water reservoir would be unable to operate in this way.

PUMPING STATION

The pumping station, which is directly connected with the north end of the filter plant group of buildings, contains nine motor oper-

ated centrifugal pumps which are used to force water to various high service reservoirs in the city. The building is 100 feet long and 46 feet wide, with a 46 foot by 20 foot wing on one side for housing the switchboard and electrical equipment. Discharge pipes and valves are in a sub-basement under the main pump floor, so as to improve the architectural appearance of the interior of the pump room. The filtered water reservoir is on three sides of the pumping station and the mixing basins are on the fourth side, so the building is entirely surrounded by water.

FIG. 6. WASHING SETTLING BASINS

Water flows to the pumps through a concrete suction well which connects directly to the filtered water reservoir, and branch concrete suction chambers 3 feet wide and 7 feet deep lead off at right angles from the suction well to the various pumps. Maximum velocities in these passages are less than 3 feet per second so that the loss of head is small. After leaving the pumps the water is forced into three separate mains, which pass through the filtered water reservoir on the way to the high level reservoirs.

Data on the size and capacities of the pumps are shown in table 2.

The pumps are of the horizontal volute type with a single stage for the low lift and two stages in series for the two high lifts. Motors are of the self starting, synchronous type, designed to operate on a 3-phase, 60 cycle, 2200 volt circuit at 100 per cent power factor. The pumps were built by the Worthington Pump and Machinery Corporation, and the motors by the Westinghouse Electric Manufacturing Co. Venturi meters made by the Builder's Iron Foundry are used in the three pump discharges, the main raw water and filtered water passages and the wash water pipe.

WATER PASSAGES

Rectangular concrete ducts or passages, instead of large pipes, are used for conveying the water through the filter plant. These

TABLE 2

Data on pumps

DATA	FIRST HIGH SERVICE	SECOND HIGH SERVICE	THIRD HIGH SERVICE
Number of pumps	3	3	3
Normal capacity, m.g.d	18	10	10
Maximum capacity, m.g.d	21	11	11
Average operating head, feet	135	220	340
Motor horse power	600	510	770
Speed, revolutions per minute	1200	1200	1200
Guaranteed overall efficiency, per cent	78.5	78.5	79.1
Actual overall efficiency, per cent	83.8	82.3	79.1

ducts are from 8 to 10 feet wide, and from 5 to 12 feet high, with walls 15 inches thick. As a rule the ducts are placed one above the other for compactness and economy. Expansion joints with steel plate water stops are provided throughout at intervals less than 50 feet apart, and inside surfaces of the ducts were waterproofed with a special asphalt compound. The ducts are all heavily reinforced for positive and negative stresses for all loading conditions and for temperature strains.

Some doubt has been expressed by sanitary engineers as to the advisability of having raw water and filtered water separated by relatively thin concrete walls. Consideration was given to this question, but the writer can hardly see how it would be of much importance on account of the extremely small leakage possible and the relatively

large quantities of water involved. It would not be advisable to do this, however, in cities where the raw water has a high colon index.

Wash water is stored in a covered concrete reservoir, 66 feet long, 35 feet wide and 12 feet deep, with a capacity of 200,000 gallons. This is located on a small hill directly east of the filter plant. As the base of this hill is only 300 feet from the filter plant and it rises to an elevation of about 100 feet above the filters, it provides an ideal situation for the reservoir. The flow line of the reservoir is 54 feet above

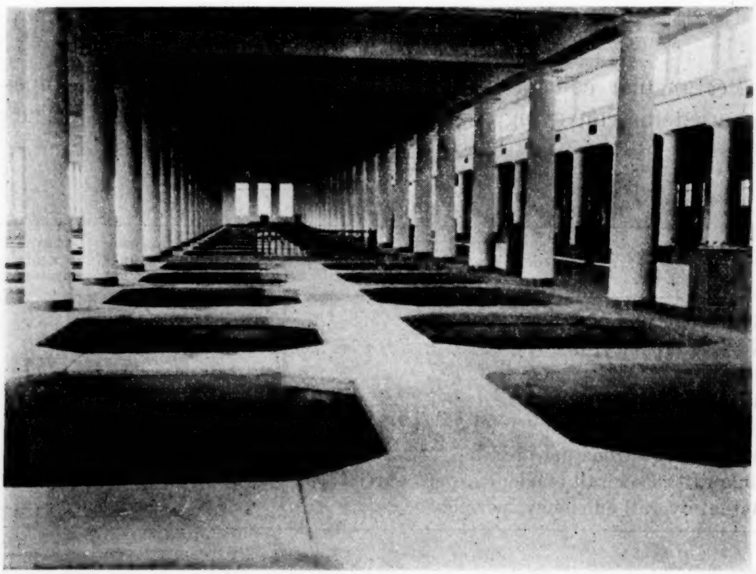

Fig. 7. Side View of Filter Building Interior

the tops of the filter gutters and this provides ample head, under full flow, for washing the most distant filter.

A 12-inch pipe connected to the discharge of the 1st high service is used to fill the reservoir. A 30-inch cast iron pipe, 1200 feet long, conducts the wash water to the filters. An automatic float valve is used to keep the wash water reservoir full at all times. The roof of the reservoir is covered with 2 feet of earth and the slopes are terraced so that the finished structure is entirely out of sight and thoroughly protected from contamination or freezing.

CHEMICAL MANUFACTURE

Syrup of alum is used as a coagulant and this material is manufactured at the filter plant by the Hoover process out of bauxite and sulphuric acid. The bauxite is transported to the plant from a railroad siding about half a mile away, and after being crushed and pulverized is lifted by vacuum to the storage bins in the tower of the head house. From these bins it is drawn off as required to lead lined boiling tanks. These bins are also used to store crystal alum to be used in case of emergency and hydrated lime which is used to control the acidity of the filtered water.

Sulphuric acid is stored in an underground vault near the head house and is lifted to the tanks by acid pumps. The manufacture of one ton (2000 pounds) of aluminum sulphate requires about 700 pounds of bauxite and 1100 pounds of 60 degree sulphuric acid. Cake or crystal alum is not made. Auxiliary equipment such as automatic scales, acid fume scrubbers and dust collecting equipment is used to facilitate the work and to keep the alum plant clean. After the syrup is made, the solution is fed without dilution to the raw water through controllers. The cost of the finished product to date without interest or depreciation is about $22.00 per ton, but this figure is not very useful as the plant has only been in operation three months.

HYDRO-ELECTRIC PLANT

The hydro-electric plant is located at the foot of a steep bank about 1000 feet away from the filter plant. Water for operating the turbines is obtained from the surplus supply from the aqueducts, which amounts to a maximum of 200 cubic feet per second under a net head of 130 feet. Electrical equipment in the power plant consists of 2 horizontal 1500 kilowatt generators, delivering 3-phase, 60 cycle, 2200 volt current. The power plant is of the remote control type fully equipped with all safety devices and capable of being operated from the pumping station switchboard at the filter plant. Standby service connections with a local power company have been made in case of a break down in the power plant. The cost of local electric power is about one cent per kilowatt hour, and the cost from the new power plant is estimated to be one-fourth of a cent per kilowatt hour, which will mean a saving of about $80,000 per year. The power plant furnishes sufficient energy for all requirements of the filter plant and pumping station.

ARCHITECTURE

The filter plant is situated in a locality which will eventually be adjacent to an extensive parkway and for this reason careful attention was given to the architectural features of the group of buildings. Many studies were made and the type finally selected was that known as the American Colonial. Familiar examples of this type of architecture, constructed about one hundred years ago, in dark red brick and white wooden gables, are found in nearly all southern cities.

FIG. 8. CENTRAL GALLERY—FILTER BUILDING

The plans were examined and approved by the Fine Arts Commission of the National Capital, which made many valuable suggestions.

Building walls are constructed of light red and brown brick of variegated colors, comprising the full range of the kiln. In places the fire flash brick is almost black and lends a pleasing variety to the structure. The main walls are composed of one layer of face brick backed up with 8 inches of interlocking tile, with a 1 inch air space for insulation. Variegated Vermont slate is used for the roof, and the gabled wooden cornices are painted a Colonial ivory color. Windows are of the steel casement type painted to match the cornice.

In order to obtain the exact appearance of brick work desired a sample wall 10 feet high and 20 feet long was erected on the site of the work, and the contractor was required to use this as a model for color and bond.

The more important interior floors in the buildings are covered with dark red and tan colored pottery tiles, and walls and ceilings are of plaster made of white cement and marble chips. The filter building, which is 361 feet long and 156 feet wide, has an exceptionally bright and well lighted interior. Ceilings and columns are white, floors and main passages are red tile and filter tops are finished cement. This treatment together with generous window and skylight facilities makes the room the best lighted, perhaps, of any filter building yet constructed. The interior treatment of pumping station and head house is similar in general to the filter building. Baseboards and stairs are dark green slate, and a substantial glazed tile is used for walls containing chemical manufacturing and feeding equipment.

The expense of this architectural treatment added somewhat to the cost of the superstructures, but it was considered justifiable on account of the location of the filter plant at the National Capital and the consequent increase in the number of people who will visit it. Materials were selected for durability as well as beauty, and the appearance of the buildings should improve with age. Twenty years ago architectural beauty was neglected on many plants, but at present there is a wise tendency to make up for this oversight. This is strikingly illustrated by the architectural treatment of the new Baldwin Plant just completed at Cleveland.

A group of six brick dwellings, matching the architecture of the main buildings, are erected near the filter plant for the use of the Senior Engineer, Superintendent and principal employees.

Notwithstanding the attention paid to effective architectural treatment and the introduction of certain units not covered in the original estimate the entire new system will be completed and tested for something like three-quarters of a million dollars less than the original estimate.

The studies, plans and construction of the new filter plant, aqueduct and other water supply structures are in charge of the Corps of Engineers of the War Department. Work on the project was begun by Major M. C. Tyler, Corps of Engineers, who continued in charge until 1923, when he was transferred to Muscles Shoals. His place was taken by Major J. A. O'Connor, Corps of Engineers,

who in turn was succeeded by Major Brehon B. Somervell, the present District Engineer. Mr. E. D. Hardy, Senior Engineer, is in direct charge of designs, construction, and operation of water supply projects. Mr. J. E. Curtis is Superintendent of construction work and the McMillan Park Filter Plant. Mr. J. W. Armstrong, Filtration Engineer for the City of Baltimore, was employed as Consulting Engineer. The writer was Resident Engineer on construction and is now Superintendent of the new Dalecarlia Filter Plant, power plant and adjacent reservoirs and pipe lines.

WATER SOFTENING PLANT AND PUMPING STATION IMPROVEMENTS AT FOSTORIA, OHIO[1]

By J. F. Laboon[2]

Just as there are trends in industry, in the stock market, in education, in sewage disposal practice and in many other activities of the human race so there is a trend in the water works field, namely, to supply soft water. It is not an easy matter for municipally owned plants to proceed to furnish a soft water supply, whether naturally or artificially softened, due to the very nature of our government, but the many softening plants now in use or in the projected state attest to the success of water works engineers not only in the design of softening works but in establishing the economics of a soft water supply for industrial use and domestic consumption. Greenville, Ohio; Jefferson City, Mo.; the Ohio Valley Water Company (supplies Bellevue, Ben Avon, McKees Rocks, West View and others in the Pittsburgh district); Apollo, Pa. and Wheeling, W. Va., of recent design by the writer's firm are now in operation. The Fostoria plant will be operating, it is hoped, by this time next year. The Sewickley, Pa., softening plant is now in the course of design and softening plants are being considered by other clients. Other engineers record like progress in the design and installation of softening plants.

Softening as employed in public water supplies generally assumes one of two types—the "lime-soda" process or the zeolite method, the type used depending upon local conditions. Of the above named plants, that of the Ohio Valley Water Company is a zeolite plant capable of softening 4 million gallons daily to zero hardness. This plant is the largest of this type so far built for softening a public water supply. For Sewickley, Pa., studies have been completed on a marked variation of one of the above named types. The Fostoria softening plant is of the "lime-soda" type, the feature of which will be the combination of the functions of clarifier and settling basins in one unit and the provision for recirculation of clarifier sludge as an enhancement in the softening process.

[1] Presented before the Central States Section meeting, September 15, 1927.

[2] Member of firm, The J. N. Chester Engineers, Pittsburgh, Pa.

EXISTING CONDITIONS

Population. The city directory of 1926 gives a population of 12,000.

Consumption. Pump displacement records taken on October 20 and 21, 1926, gave a minimum rate of 1, a maximum of 1.81 and an average of 1.4 m.g.d., while on December 19, 1926, the rate between 3 and 4 p.m. was 2 m.g.d. under normal conditions of pumpage.

The water, as now served to consumers, is not chlorinated and its use is reserved to general purposes other than drinking and cooking. It is anticipated the consumption will increase upon completion of the improvements, when a safe, clear and soft water will be available.

Quality. Samples of water taken in October, 1926, from the reservoir intake and the deep well located in the existing slow sand filters, analyzed as follows:

	RESERVOIR	DEEP WELL
	p.p.m.	*p.p.m.*
Turbidity	20	30
Total Iron	0.1	9
Free CO^2	10	18
Chlorides	10	21
Magnesium	14.4	49
Alkalinity	68	133
Total Hardness	137	357
Incrustants	69	224

It is said that the reservoir water has, as a rule, run considerably harder than the results of the analysis shown above, presumably during the dry months of the year, and that the results given herein are less than average.

Existing works. The present supply is taken from the east branch of the Portage River and impounded in three reservoirs having a combined capacity of 290,000,000 gallons.

During dry spells, it has been found necessary to take water from a 24-inch well drilled several years ago in the existing slow sand filter.

PROPOSED IMPROVEMENTS

Softening plant

It is proposed to construct a softening plant adjoining the existing pumping station, having a nominal capacity of 3 m.g.d. The site

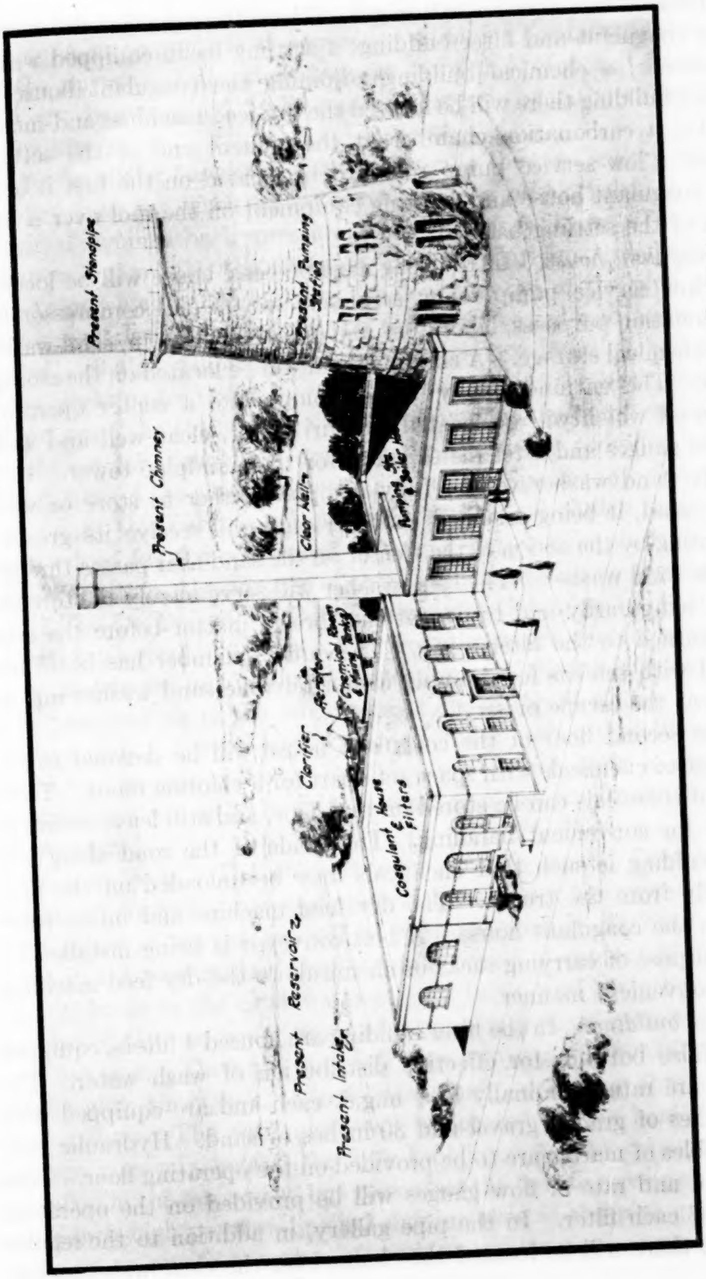

FIG. 1. FOSTORIA, OHIO, WATER SOFTENING PLANT AND PUMPING STATION

will permit of extension to 9 m.g.d. The softening plant will consist of a coagulant and filter building; a settling basin equipped with a thickener; a chemical building adjoining the coagulant house, in which building there will be located the dry feed machines and mixing tanks; a carbonation chamber at the effluent end of the settling basin; a low service pump room to be located on the first floor of the coagulant house and aerating equipment on the roof over a portion of the settling basin.

Coagulant house. In the coagulant or head house will be located the low service pump room, scrubbers, driers and compressor for carbonation purposes, laboratory and office, toilet room, sand washer and chemical storage. A chlorine room will be located on the storage floor. The entrance lobby will accommodate a center operating table on which will be located Venturi meter, clear well and wash water gauges and a telemeter gauge for the standpipe tower.

The sand washer will be fully equipped either to store or wash filter sand, it being assumed that the sand will receive its greatest cleansing by the action of the ejector on the sand as it passes through to the sand washer. The sand washer will serve merely to store the sand temporarily and to decant the foreign matter before the sand is returned to the filter again. The outlet chamber has been provided with screens for draining completely the sand washer and to prevent the escape of sand.

The second floor of the coagulant house will be devoted to the storage of chemicals with space set apart for a chlorine room. Three cars of chemicals can be stored on this floor, and still leave sufficient space for convenient handling. The grade of the road along side the building is such that chemicals may be unloaded on the floor directly from the trucks. The dry feed machine and mixer room adjoin the coagulant house. A belt conveyor is being installed for the purpose of carrying sacks of chemicals to the dry feed machines in a convenient manner.

Filter building. In the filter building are housed 4 filters, equipped with false bottoms for effective distribution of wash water. The filters are rated nominally at $\frac{3}{4}$ m.g.d. each and are equipped with 18 inches of graded gravel and 30 inches of sand. Hydraulic control tables of marble are to be provided on the operating floor. Loss of head and rate of flow gauges will be provided on the operating table of each filter. In the pipe gallery, in addition to the regular piping, there will be located the channel for the clear water piping.

leading from the clear wells under the filters to the clear water storage basin. A sump pump is also provided adjoining the by-pass channel for the purpose of emitting drainage from the plant and from the clarifier when required. The building extends over the entire area of the filters.

Clarifier sludge handling. The drainage in the pipe gallery will be pumped into the wash water sewer where a check valve is being provided against back pressure when washing filters. The sump pump will also take the drainage from the clarifiers, the discharge pipe from which will rise above the floor line out of the pipe pit so that the sludge discharge may be readily observed and easily controlled. Sludge will discharge by gravity into the 18-inch wash water sewer under normal conditions, but should the back pressure be too great the clarifier pipe will overflow into the pump sump. A connection for completely draining the clarifier is provided at the lowest level of the sludge pipe draining the sludge line into the pump sump. At this point a motor driven centrifugal sludge pump will be provided for the purpose of returning the clarifier sludge to the mixing tanks for the purpose of catalytic action, such as was demonstrated by Dr. Bull of the Dorr Company at Columbus in his experimental work recently. The piping from the return sludge pump will be carried to the mixing tanks connecting with the influent line with a by-pass leading to the mixing tanks above the flow line.

Clear wells. A clear well is located under each of the filters, divided by the pipe gallery. Each clear well will have a capacity of 34,500 gallons or 33 minutes detention at the maximum capacity of the plant.

Chlorine room. The chlorine room on the second floor of the coagulant house is to be equipped with two chlorinators and scales. Two points of application will be provided—one in the clear water main in the pipe gallery, thus giving a period of contact of at least several hours in the clear water storage basin, and the other in the suction of the raw water pumps for pre-chlorination when required.

Wash tank. The wash tank will have a capacity of 50,000 gallons, discharging through a 14-inch wash main extending through the pipe gallery. The wash tank will be located on the banks of the storage reservoir, behind the filter building. A gate valve is being installed in the main wash line to control the flow to any or all filters. An 8-inch high pressure line is being installed in the pipe gallery to serve as an auxiliary source of wash water, its use being necessary when the wash tank may require repainting.

Settling-clarifier basin. The settling-clarifier basin will be equipped with clarifier apparatus and will be 50 feet square and 16 feet deep to the flow line at the center, giving a detention period of two hours at 3 m.g.d. or 3 hours at 2 m.g.d. It is not expected that the consumption will average more than 1.5 m.g.d. for sometime to come or at the most 2 m.g.d., so the detention period will be at least 3 hours under normal conditions. The influent wall is perforated to give as nearly perfect distribution as can be had. A slotted opening is provided at the bottom throughout the length of the distributing wall so that solids may drop through to the bottom of the clarifier. The effluent wall is equipped with adjustable baffle weirs so as to make possible a level flow into the carbonating chamber, thus foregoing any drop from one level to the other, and the consequent breaking up of the floc. On the settling basin face of the effluent baffle wall, there has been provided a wood deflector so as to throw back any bottom currents following the bottom and effluent wall, tending to carry sludge laden streams over the effluent weir. The channels leading from the mixing tanks to the influent chamber are designed to give low velocities and are equipped with deflector plates for the purpose of guiding the water stream without undue impingements.

Aerating equipment. Due to the stagnant character of the water after passing through the storage reservoirs the raw water contains considerable odor. To correct this condition aeration equipment has been provided over a portion of the settling basin where aeration may be accomplished during the summer months or other periods of the year when required. Three lines of 8 inch pipe extend across the aerating chamber, feeding 29 aerating nozzles, each having a capacity of at least 75 g.p.m. Louvers are being constructed around the aerating chamber to protect the building and to prevent undue scattering of the aerated water by the winds. The piping is so arranged as to permit by-passing the aerating chamber so that the raw water may flow directly to the mixers.

Mixing tanks and dry feed machines. Four dry feed machines are being provided for feeding lime, soda and alum or iron with one machine remaining in reserve. The chemicals will discharge directly into the influent lines leading to the mixing tanks. The two mixing tanks have a total detention period of 30 minutes at the 3 m.g.d. rate and are equipped with mechanical stirring equipment so designed as to prevent bottom deposits. Side deflector vanes are being in-

stalled in both tanks at two points to prevent circumferential flow and to give more complete agitation. The influent lines will connect at the bottom of the tanks and the troughs will carry the effluents from the top of the mixing tanks to the settling basin immediately adjacent. The mixing tanks are arranged to give either series or multiple operation. Both tanks are enclosed by building above and around the outside.

Carbonating equipment. A carbonation chamber having a minimum detention period of five minutes is provided at the effluent end of the settling basin. A hot water heater fired with coke or gas is being installed in the structure adjacent the mixing tanks, together with a motor driven compressor, a scrubber and drier. The CO_2 gas will be measured and recorded and carried to the bottom of the carbonating chamber.

Clear water storage basin

The existing high service circular suction well is to be covered and used as a clear water storage basin from which the high service pumps will take their suction. The clear water basin with the clear wells under the filters, when full, will have a total capacity of 645,000 gallons. The roof is to be of reinforced concrete designed to permit of an earth fill 18 inches deep.

Low service pumps

Two steam driven low service pumps are to be provided, each with a capacity of 3 m.g.d. They are to be located in the low service pump room on the first floor of the coagulant house. Suction will be taken through an 18-inch line connecting with the existing line coming from the storage reservoir intake. The pumps will discharge into the aerators or the mixing tanks. The low service suction line is also connected to the abandoned slow sand filters from which suction may be taken by the low service pumps when the storage reservoirs are low. A 24 inch drilled well, located in one of the slow sand filters, may be used as an auxiliary supply, the deep well pump discharging into the slow sand filters. The diversion dam at the creek is to be reconstructed so as to permit of drawing water into the slow sand filters.

High service pump and force main

A 3 m.g.d. cross compound high service pump is to be installed in the existing pumping station in a room which will be extended and

reconstructed to accommodate the pump. The pump will discharge into a new 16 inch and 14 inch main, which is to be constructed as an auxiliary to the existing 14 inch main. The old and the new 14-inch mains will cross connect at the pumping station. The new 14-inch main will extend to Vine Street, connecting to the distribution system at that point.

Venturi meter

A Venturi meter will be installed in the new 14-inch force main to measure the pumpage. Since the new pump will be used probably 90 to 95 per cent of the pumping hours, this Venturi meter will record practically all of the flow from the plant, but should the cross compound pump be down the displacement of the existing high service pump may be taken and added to the Venturi meter readings to obtain the total flow for any period.

Hydraulic fire valve

The existing hand operated gate valve in the force main leading to the standpipe tower will be replaced with a hydraulically controlled gate valve for the purpose of hurriedly shutting off the standpipe in case of fire. Under such circumstances pumpage is direct into the distribution system at a pressure of 110 pounds.

COST

The cost of the completed improvements was estimated as $194,500. Bids taken October 6, 1927, on all of the work, including the high service pump, on which bids were taken in January, 1928, resulted in the award of the following contracts:

Contract	
29 Excavation, Grading and Concrete Work and Super-Structures	$ 93,000
30 Pump Station Water Piping	7,100
31 Pump Station Steam Piping	2,125
32 Filter Equipment	35,720
33 Furnishing Clarifier	7,827
34-B Furnishing and Installing Wash Water Tank	3,850
35 Furnishing and Installing Engine Driven Low Service Pumps	4,047
36 High Service Cross Compound Pump	22,837
37 Furnishing and Installing Motor Driven Air Compressor	860
Making the total cost of the improvements	$177,366

THE WATER SUPPLY AND HYDRO-ELECTRIC PLANT AT SPARTANBURG, SOUTH CAROLINA[1]

By Herman F. Wiedeman[2]

The favorable topographical and hydrological conditions, which existed at the proposed site of Spartanburg's new water supply works, led to the construction of a hydro-electric plant as part of the water works development.

The plant, which has now been in operation for one year, furnishes filtered water to the city, generates the power necessary to pump the water and sells all its excess power to a local power company at the water works switchboard.

A small independent hydro-electric plant is often unsuccessful economically, particularly when the stream flow is irregular, and the marketing and distribution of the power is costly. When such a plant is operated in connection with a water supply works, however, using a large portion of the energy without transmission or distribution costs, as at Spartanburg, the initial cost and the cost of operation are reduced, and the plant may be operated profitably.

ORIGINAL PUMPING AND PURIFICATION PLANT

The original water supply of Spartanburg was obtained from a small stream near the city known as Chinquapin Creek, on which was constructed an impounding reservoir of 5 million gallons capacity, which supplied raw water, by gravity, to a coagulation basin, and a filtration plant of the wood tub type. After filtration, the water was pumped by a combination of steam and electric pumps to the distribution system. As the demand increased, additional supplies were obtained first from Shoally Creek and later from Lawsons Fork, both of which were in an adjacent drainage area. Raw water was then pumped, by electrically driven centrifugal pumps, from these supplies to the reservoir on Chinquapin Creek. The supply from Chinquapin Creek was small and it was necessary to obtain the major portion

[1] Presented before the Chicago Convention, June 8, 1927.

[2] Of Wiedeman and Singleton, Inc., Consulting Engineers, Atlanta, Ga.

of the raw water from the two supplementary sources. Since these sources lay in an adjacent drainage area, the energy consumed in pumping over the ridge between the two drainage areas, with a difference in elevation of 130 feet, was lost, and the total raw water pumping head was increased about 50 per cent.

Early in 1923, it became evident that increased capacity was necessary to enable the plant to meet the rapidly increasing demand.

An examination of the plant indicated that it was rapidly approaching the end of its useful life, that the physical arrangement and topography surrounding the plant prevented economical expansion, and that the industrial development and growth of population on the drainage areas, was becoming a menace and would eventually force the city to change its source of supply. Accordingly, it was decided to add sufficient capacity to the existing plant to enable it to meet the demands of the next 5 years and then to seek a new supply.

Investigation of the available sources of supply indicated that the South Pacolet River about 12 miles from the city offered the best solution of the problem, and it was decided to purchase the necessary land and build the plant when it became necessary. About this time, however, the Southern Railway announced its decision to build a large car repair shop at Spartanburg, and chose a location which was on the drainage area of both the creeks from which the water plant was receiving its supply and not far above the intakes. Subdivisions were contemplated in the vicinity of the site, and it was evident that a very undesirable condition would be created from the water works viewpoint if the shops were constructed where planned.

It was not practical, however, to change the location of the proposed shop because of trackage facilities, and other reasons, and the shops were too great an asset to lose because they interfered with an almost obsolete water supply. It was therefore decided to construct the new supply immediately.

THE SOUTH PACOLET RIVER

The South Pacolet River, which was selected as the source of the new water supply, rises in the foothills of the Blue Ridge Mountains at an elevation of 2000 feet above sea level, and descends rapidly to an elevation of 1000 feet, which is the general level of the plateau. It flows in a southeasterly direction to its junction with the North Pacolet River to form the Pacolet River, which is tributary to the Broad River of the Carolinas. At least 35 per cent of its entire

drainage area of 120 square miles is rugged mountainous country with a population of not more than 5 persons per square mile. It has been estimated that the population of the entire watershed does not exceed 22 persons per square mile. The topography of this section is such that there is little possibility of future industrial development. Since the North Pacolet River carries the sewage of a number of towns and mills on its drainage area, and conditions in this section are favorable for industrial growth, which is already being manifested by the construction of new mills and the growth of its towns, it was decided to locate the intake on the South Pacolet River immediately above the junction of the two streams.

RAINFALL

The rainfall conditions in the drainage area are particularly interesting because of the wide variation of the rainfall at different stations on the drainage area.

Table 1 shows the average rainfall for the 10-year period 1915 to 1925 at two stations, Spartanburg and Landrum, which are 20 miles apart. It will be noted that the average annual rainfall at Spartanburg was 49.64 inches, while that at Landrum was 62.67 inches. The latter figure prevails over the mountainous portion of the drainage area which constitutes 35 per cent of the entire area. It might be said that the average rainfall on the entire drainage area is approximately 54 inches per annum.

HYDRO-ELECTRIC POWER POSSIBILITIES

Early studies of the project indicated that the development of hydro-electric power was feasible, because of the natural advantages of the site. The river passed through a comparatively narrow rocky gorge, and over shoals which made a head of 63 feet available with a flooded area of 350 acres. From the run-off data available, it was estimated that it was possible to obtain, under average conditions, 4,000,000 kilowatt hours of energy per year, of which 1,500,000 kilowatt hours would be required the first year in the water plant for pumping and miscellaneous use. Further investigation showed that at least two of the power companies operating in that section were willing to contract for all excess energy on a dump power basis. Estimates of the cost of development indicated that it would be possible to develop this power economically, since all the power could

be used or sold at the switchboard without any distribution costs and at a small operating expense.

GENERAL PLAN OF DEVELOPMENT

A reinforced concrete dam was constructed across the river above a series of shoals and water was conveyed through a penstock to the power house. The filtration plant was located near the power house receiving its raw water by gravity through a 24-inch cast iron connection to the penstock and discharging the filtered water into a clear well below the filters. The pumps located in the power house take suction from this well and discharge through a 24-inch cast iron pipe line to a high level reservoir from which the water flows by gravity through a cast iron main to the city.

FILTER PLANT

The raw water is received from the storage reservoir, by gravity at the mixing basin, the flow being controlled by an hydraulic valve in the influent line which is operated by a float set to maintain a predetermined level in the coagulation basins. The mixing basin is of gravity type with over and under baffles and has a retention period of 30 minutes at 6 m.g.d. rate. The walls supporting the wood baffles are of concrete fitted with slots so that the baffle spacing may be varied to give any desired velocity, and 3 sluice gates are provided at the outlet of the basin to vary the retention period. After leaving the mixing basin, the water flows through an open flume to the inlet end of the coagulation basins, which are two in number and have a combined retention period of 6 hours at 6 m.g.d. rate. The water enters the coagulation basins through 6 shear gates, 3 in each basin, and is drawn off over a weir at the opposite end of the basin, to the filters. Lime and sulphate of alumina are fed by dry feed machines. The filters are of the conventional type, 6 in number of 1 m.g.d. capacity each, and discharge the filtered water into a 750,000 gallon clear well constructed under the filters.

Chemical and bacterial laboratories and general offices are provided in the filter building.

POWER HOUSE

The power house is located immediately adjacent to the filter plant. It contains two vertical water turbines of 750 h.p. capacity each

under 55 foot head. Water is conveyed from the dam to the turbines by a 78-inch riveted steel penstock about 1200 feet long, which connects with two 54-inch steel penstocks, supplying water to the turbines. Hydraulic gate valves are set in the wheel pit to control the flow through the penstocks and a steel differential surge tank is connected to the lower end of the 78-inch penstock to provide regulation and to protect the penstock from excessive pressures, due to the surges caused by the change in or rejection of load. A generator of 625 KVA capacity is connected to each turbine. Exciters are direct connected.

Switchboards are so arranged that all power generated may be given to the power company or that a portion of the power may be used in the plant and the excess given to the power company, or, if the plant is not in operation, power may be received from the power

TABLE 1

Average monthly rainfall in inches for period 1915–1925, at Spartanburg and Landrum, S. C.

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	ANNUAL
Spartanburg...	5.09	4.85	4.60	4.30	4.47	3.04	6.72	3.43	3.71	2.80	2.81	3.74	49.64
Landrum.......	6.41	5.06	4.87	5.01	6.72	4.86	7.51	4.88	4.37	4.31	3.50	5.17	62.67

company for pumping and other purposes. The output of each machine is metered and meters are provided for incoming and outgoing power on the power company's lines. Generation is at 2300 volts which is the voltage at which the pump motors operate, while transmission is at 33,000 volts. The water department's lines extend only to the low tension side of the transformers which are located outside of the power house. Transformers and transmission lines are owned and maintained by the Power Company. The generating and governing equipment is provided with alarms and protective equipment making constant attendance unnecessary.

The pumping equipment which is located on the lower floor of the power house, consists of 3 two-stage centrifugal pumps of 4,000,000 gallons per day capacity each against 300 feet head. The pumps are driven by 300 h.p. 2300 volt slip-ring motors, and take their suction from a common suction header connected to the clear

well. They discharge through a venturi meter into a 24-inch cast iron pipe line to the high level reservoir. Control panels for these motors are located on the generator floor above the pumps, where the operator is able to observe the instruments on the generating board when he starts the pumps. The pumps may be shut down by a push button from the pump floor. At low stages of the clear well, it is necessary to prime the pumps. This is accomplished by duplicate water ejectors, one connected to the force main, the other to the penstock.

FORCE MAIN AND GRAVITY SUPPLY MAIN

The force main is 24-inch cast iron pipe, discharging into a 3 million gallon high level reservoir and is 15,000 feet long. The gravity supply main is cast iron, 27.56 inches in diameter, and 40,000 feet long, and has a capacity at proper operating pressures of 8 million gallons per day rate.

A million gallon capacity elevated tank will be installed on the supply main near the point of distribution, to equalize pressures and provide storage to prevent interruption of service in case of a break in the pipe line.

The pipe lines, for practically their entire length, are laid in a county road. The line could have been shortened at least three-fourths of a mile by taking the most direct route, but the advantage of free right-of-way, and ease of construction, inspection and maintenance, made the longer route the most economical one.

The leakage tests made upon this line are of interest. They are shown in table 2.

The maximum leakage permitted was specified as 100 gallons per inch of diameter per mile of pipe per 24 hours.

All joints were of lead caulked with pneumatic tools. The line was laid under exceptionally good conditions.

The first series of tests were made at 150 pounds pressure by bringing one mile sections of the line up to test pressure and allowing the pressure to drop for the duration of the test, usually 3 to 4 hours. The pressure was restored at the end of the period and the amount of water required was measured. Every effort was made to eliminate air from the line, but the results indicate that a considerable amount remained. On the final tests, the force main and gravity supply main were tested as units, by maintaining a pressure 15 pounds in excess of the working pressure, for 2 hours, measuring the amount of

water necessary to maintain the pressure. A small triplex pump, taking suction from container of known capacity, was used in making the tests. Tests to determine the value of C in Hazen and Williams formula gave a value of 121 for the gravity supply line.

TABLE 2

Leakage test on cast iron supply main at Spartanburg, S. C.

DATE OF TEST	DIAMETER OF PIPE	LENGTH TESTED	DURATION OF TEST	PRESSURE		WATER NECESSARY TO RESTORE INITIAL PRESSURE	LEAKAGE PER INCH DIAMETER PER MILE PER 24 HOURS
				Initial	Final		
	inches	*miles*	*hours*	*pounds per square inch*	*pounds per square inch*	*gallons*	*gallons*
October 26, 1925	27.56	0.98	4.0	150	65	79	17.4
November 9, 1925	27.56	1.23	4.0	150	122	52	9.0
December 19, 1925	27.56	1.41	4.0	150	90	97	15.0
March 29, 1926	27.56	0.80	3.0	100	37	100	36.32
April 14, 1926	27.56	1.07	3.0	100	41	135	36.64
May 5, 1926	27.56	7.57	14.0	40	22	1,450	11.90
September 10, 1926	24.00	2.3	3.5	150	135	40	4.94

Final test constant pressure maintained

DATE OF TEST	DIAMETER OF PIPE	LENGTH TESTED	DURATION OF TEST	PRESSURE MAINTAINED DURING TEST	WATER NECESSARY TO MAINTAIN PRESSURE	LEAKAGE PER INCH DIAMETER PER MILE PER 24 HOURS
	inches	*miles*	*hours*	*pounds per square inch*	*gallons*	*gallons*
May 7, 1926	24.00	2.77	2.0	70	50	9.0
May 6, 1926	27.56	7.57	2.0	40	200	11.52

POWER PLANT OPERATION

Before the plant was completed, a 10-year contract was entered into with one of the local power companies for the purchase of all power generated in excess of that required for pumping and miscellaneous use at the plant. This contract also provided that the power company should furnish power to the water department, when and as required. The total capacity of the power company is

very large when compared with the capacity of the department's plant, and this in itself has resulted in extremely satisfactory electrical operating conditions. Once the plant is synchronized with and connected to the power company's lines, its speed is controlled by the power company's machines, as well as its own governors, and the 300 h.p. motors may be started without the usual difficulties of speed regulation, which some times accompany abrupt changes in load in small plants. The power company is also able to absorb the full capacity of the plant at any time.

The plant has no peak load, and no definite load factor, consequently it is possible to vary the load to suit water conditions and obtain the maximum amount of power from the development.

The operating force required for the filtration plant and the hydroelectric plant consists of one chief operator, three shift operators and one janitor. These men would be required, in any case, for the operation of the filtration plant and pumping station, consequently there is no additional labor charge for the operation of the hydroelectric plant. No difficulty has been experienced in obtaining efficient operation of filters and power plant with this force. In fact, the men seem to have the usual amount of leisure time which most filter plant operators have in plants of this size.

RESULT OF FIRST YEAR OF OPERATION

Operating records are now available for the first ten months of operation and it is possible to forecast the power production for the balance of the period with sufficient accuracy to determine whether or not the power project is a profitable one.

Figure 1 shows graphically the power generated, sold and used for pumping. It also shows the relation of the rainfall for the first 10 months to the average rainfall. For this period there was a deficiency of 7.23 inches, or approximately 20 per cent.

The years 1925 and 1926 were years of severe drought in the Piedmont Section of the Southeast, but yet the plant was able to generate approximately 3,500,000 kilowatt hours of energy. There was sufficient power at all times for pumping purposes.

OPERATING

The gross return from the operation of the power plant, consists of (1) power sold, (2) power used, and (3) power saved by elimination of low lift pumping.

In computing the revenue from the power plant, the power used in pumping water is credited to the power plant at 1.34 cents per kilowatt hour, which is the commercial rate at which the water department buys power from the power company.

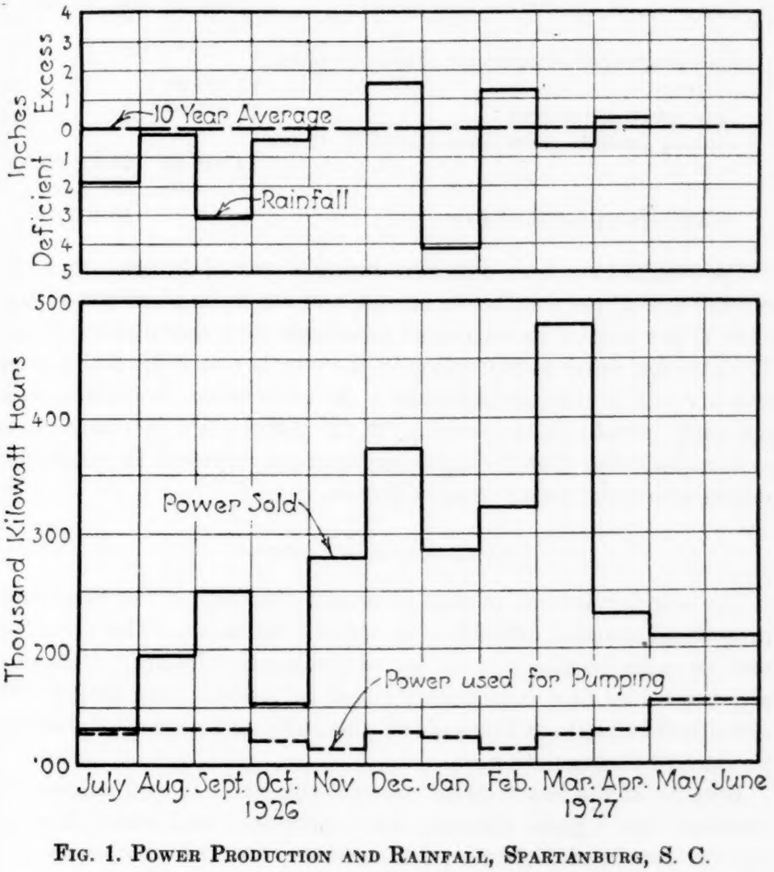

FIG. 1. POWER PRODUCTION AND RAINFALL, SPARTANBURG, S. C.

The power saved by the elimination of low lift pumping, which would have been necessary had the dam not been constructed, is also credited at the same rate.

The actual cost of constructing the power plant was $450,000.00 and deducting the cost of a low lift pumping station and diversion estimated at $55,000.00, which would have been necessary had the power project not been constructed, leaves a net cost to be charged to

power of $395,000.00. Assuming an average life of 35 years, the revenue from the operation of the hydro-electric plant is as follows:

Power sold, 1,764,000 kw. hrs. @0.005¢	$8,820.00	
Power used, 1,463,000 kw. hrs. @1.34 ¢	19,604.20	
Power saved, 200,700 kw. hrs. @1.34 ¢	2,698.38	$31,122.58
Operating expense, insurance, supplies, repairs, etc.	$2,400.00	
Interest @ 4½ per cent	17,775.00	
Sinking fund 35 years compounded @ 4½ per cent	4,846.65	25,021.65
Profit from operation of plant		$6,100.93

The results have been obtained during a year of drought when the rainfall was 20 per cent below normal and when the plant was selling over 50 per cent of its output at a low rate on a dump power basis. The average water consumption in the city is now 3,500,000 gallons per day and is increasing rapidly. As more power is consumed in pumping operations, the earnings of the power plant increase. It is evident therefore that the figures given above represent the minimum return which the power plant will earn.

FILTER PLANT OPERATION

The surface waters of the Piedmont Section of the Southeast present no unusual difficulties as regards filtration. The turbidity may be easily removed by the use of aluminum sulphate. Occasionally the use of lime is necessary either to produce coagulation with aluminum sulphate at times of low alkalinity, or to correct the effects produced by coagulation.

Because of the low mineral content, the water is well adapted to industrial use. Some difficulty was experienced with algae, shortening the length of filter runs last summer, but this was easily corrected by the use of copper sulphate in the reservoir.

POLICY OF THE WATER COMMISSIONERS

The policy of the Water Commissioners has been to take the public fully into its confidence and the result has been that they have the whole-hearted coöperation of the citizens. As soon as the plant was completed, a prominent landscape engineer was employed to lay out

a park on the water works grounds, which comprise approximately 200 acres of land admirably suited for such a purpose, and readily accessible to the city over good roads.

Picnic grounds and camp sites are provided and the public is invited to visit the plant and make use of the grounds. The park work is being carried on by R. B. Simms, Superintendent of Water Works, along a definite plan as funds became available each year. Ultimately, Spartanburg's Water Works Park will be the equal of any in the city.

IRON REMOVAL PLANT AT CHAMPAIGN, ILLINOIS[1]

By Frank C. Amsbary, Jr.[2]

Iron bearing water is rather a disagreeable water. It stains the plumbing fixtures and has a slight brown color when drawn from the faucet. The fungus that lives on iron, called crenothrix, grows in the mains and at times stops up small services. It is torn loose from the sides of the main during fire, giving the consumers a supply of of this stringy mossy substance.

Complaints were numerous and our troubles at Champaign and Urbana seemed to be increasing, so in 1911, under the direction of A. N. Talbot, of the University of Illinois, the first four beds were designed, constructed and placed into operation. The water was to be aerated, thereby oxidizing the iron, and oxidized iron would be easy to remove. To aerate the water a splash board was constructed so that the water from the discharge of every well would drop on it and splash out into a spray. To give added aeration the influent of each filter was installed in a vertical position, with the water entering in a vertical jet, like a fountain. As this water with the iron in an oxidized form would pass through the bed the iron would be removed. For a while we thought that our troubles were at an end, but in reality they had only started. Our old friend crenothrix found more food in the filter beds than ever had been found in the mains and as a result thrived beyond all power of prediction. We found soon that we had beds so massed with fungi that water would not pass through after a few hours of operation, and washing did not seem to remove them.

There were many suggestions made to rid us of this trouble and none worked. One was a water jet. A grid was constructed just a few inches above the sand bed. On the bottom side of this grid numerous pin holes were drilled and then water pumped into it under high pressure. The thought was that these jets of water digging their way into the bed during the wash would tear the crenothrix loose and

[1] Presented before the Illinois Section meeting, January 28, 1927.

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the wash water would carry it away. For a short time, but a very short time, it was thought that the solution had been found, only to find the beds once more clogging up.

Another suggestion was then made, that of jetting steam into the beds rather than water. So steam was tried. This killed, or rather cooked and as a result killed the crenothrix, and the beds operated very nicely. Once more the solution of the trouble was thought to have been found. But it was not very long before complaints of bad taste and smell of the water were being phoned into the office. This was traced directly to the steam jets and they were removed.

The above gives a brief résumé of a few of the things tried, their results and some idea of what the management was going through until at last a real solution was found. The State Water Survey, then under the direction of Dr. Bartow, suggested that we try chlorine. A chlorinator was installed and prechlorination was started with amazing results. It not only prevented the growth of crenothrix, but killed all that was in the beds. Soon our filters were running along without any troubles at 98.99, and even 100 per cent removal of iron.

Up to 1923 we were running along smoothly, with one more filter added and every one happy. In the meantime our wells were spread out to the north with one as far away from the receiving basin as a mile and a half. I merely mention it at this time for later reference, and also to give you, as they appeared, factors which later have proved as agents in the success and failure of the plant's operation.

In 1924 two more filters were constructed. These filters were built under very rigid specifications as to the size of wash troughs, gradation of the gravel and sand, (by the way no gravel was used in the beds of the other five filters, only sand), and also the rate of rise during the wash. The air wash was left out because it has been proved that air wash was not necessary at other filter plants when the troughs, gradation of gravel and sand, and the rate of rise during wash was as stated in our specifications. The brass strainer system was replaced for the 2 inch pipe grid drilled every 6 inches on the under side. We expected great things for every modern proved plan of filtration was rigidly followed. But once more we were badly fooled. The first day the filters only operated six hours and refused to let another drop of water through. We were not very much excited realizing that very likely silt in the sand was the cause. So we skimmed a little sand off of the top and then washed the bed. It washed up very slowly requiring from 50 to 100 per cent more time to wash, and using

a rise of twice that used in the 5 old beds. As time went on our troubles increased rapidly with the two new beds. They stopped up and never ran through the twenty-four hours that the other beds did. They would clog and would not wash clean even after from twenty to twenty-five minutes, while the old beds using half the amount of water were washed in ten to twelve minutes. This is quite a factor in our operation costs as 60 per cent of our power cost alone is to get the water into the receiving basin. Here we were using twice the amount of this previous water to wash one of these filters as was used to wash any one of the old beds. There were days when the filter operator was unable to break through the bed at all with the wash water without starting up an extra pump, the bed was in such a packed condition.

Tests showed that these two beds were removing only 50 to 60 per cent of the iron and we were beginning to get complaints of crenothrix, which showed that too much iron was getting into the mains and the growth was starting up again. Something had to be done. We did the only thing, that is, we changed the only thing that was fundamentally different from the old beds. We put air wash in two new filters. This was done by alternating an air pipe between each strainer in the effluent grid, leaving 12 inches of $1\frac{1}{4}$ inch gravel and 36 inches of torpedo sand. Since the change, we are washing the two new beds in half the time that we were taking before, and as a result using half the amount of water. Our tests taken this past week show that they pass just a "trace" of iron. They are not washed at any more frequent intervals then any of the others. By the addition of the air wash our troubles came to an end with these two new beds.

Since that time two new wells have been drilled about a mile from the plant furnishing 1000 g.p.m. through a common discharge line with 17 other wells. Since that time we have been having more or less trouble in not attaining complete removal of the iron, but we are convinced that, because of this added volume of water, it is not receiving proper aeration. At the present time we are constructing a new aerator, which we hope will once more put us on easy street, for a while at least.

DISCUSSION

J. P. Hanley: What air pressure and what water pressure do you use in washing?

FRANK C. AMSBARY, JR.: We use a water pressure of 30 feet and an air pressure of from 15 to 20 pounds per square inch. The rise is 24 inches per minute in the new filters and 12 inches per minute in the old filters.

H. E. BABBITT: What about the red worms which are sometimes delivered to the consumer?

F. C. AMSBARY, JR.: There is a gnat, of the kind often seen over ponds and usually seen in great swarms which do not move, which lays eggs in the water. The eggs develop into a red worm which grows in the bottom of the reservoir from which they are pumped into the mains. The reservoirs are covered and we now operate a blower near the windows at which the gnats congregate. We expect in this way eventually to remove all of the gnats from the reservoir.

A. V. GRAF: Chironomus is the name of the organism. Chlorine is not effective in killing the worms.

JOHN R. BAYLIS: Organisms of this type can work through coagulating basins and filters.

FRANK C. AMSBARY, JR.: Dr. Forbes, Chief of the State Natural History Survey, states that the organism thrives only in pure water, but this seems to give no satisfaction to our customers.

FILTRATION OF LAKE ONTARIO WATER[1]

By James M. Caird[2]

Several places within New York State obtain their water supply from Lake Ontario by filtering it before delivery to consumers. The largest plant is that of the Rochester and Lake Ontario Water Company, supplying part of the City of Rochester and the suburbs.

In the 1908 Proceedings of the American Water Works Association, attention was called to this water filtration plant. From time to time since that date, additions and improvements have been added to this plant, so that it contains the latest improvements in the art of water filtration.

This plant is located at Charlotte, N. Y., about one and one-half miles west of the Genesee River. The intake extends about 4000 feet into the Lake and is about one and one-fourth miles west of the light house on the pier at the mouth of the Genesee River. The water is pumped to a concrete coagulation basin, having a capacity of 900,000 gallons. This basin has recently been covered to prevent ice troubles. The sulphate of alumina, which is used as the coagulant, is added to the water before it enters the basin. The amounts used are shown in table 1.

The average amount of sulphate of alumina used is equal to about 75 pounds per million gallons.

The hydrogen-ion concentration, which is over pH 7, does not seem to interfere with proper coagulation.

As the raw water is free from color and turbidity part of the year it is unnecessary to use sulphate of alumina at all times.

Liquid chlorine is used as the disinfecting reagent. The dose is divided, about two-thirds being added to the water before it enters the basin and the remainder added to the effluent from the basin before filtration. The divided dose of liquid chlorine has proved very effective and in this way the operators are able to maintain the

[1] Presented before the New York Section meeting, October 28, 1927.

[2] Chemist and Bacteriologist, Troy, N. Y.

desired amount of residual chlorine at all times. The amounts applied are shown in table 2.

The total average amount of liquid chlorine used is equal to about 2.3 pounds per million gallons of water.

TABLE 1

Sulphate of alumina

Grains per gallon

YEAR	MAXIMUM	MINIMUM	AVERAGE
1917	4.39	0.00	0.62
1918	1.62	0.00	0.36
1919	2.50	0.00	0.48
1920	2.76	0.10	0.52
1921	2.86	0.00	0.48
1922	2.49	0.00	0.53
1923	4.29	0.00	0.49
1924	1.92	0.00	0.53
1925	2.15	0.00	0.58
1926	1.91	0.00	0.62
Average 10 years..	2.69	0.01	0.52

TABLE 2

Liquid chlorine

Grains per gallon

YEAR	MAXIMUM	MINIMUM	AVERAGE
1917	0.024	0.017	0.020
1918	0.037	0.009	0.013
1919	0.029	0.009	0.017
1920	0.020	0.010	0.014
1921	0.029	0.010	0.015
1922	0.023	0.007	0.014
1923	0.026	0.007	0.015
1924	0.022	0.009	0.014
1925	0.024	0.010	0.016
1926	0.025	0.011	0.017
Average 10 years..	0.026	0.010	0.016

The water passes through the coagulation basin to the suction well of the high duty pumps and thence through the pressure filters to the consumers. These filters contain graded gravel and sand similar to that used in standard gravity filters. These filters are

equipped with rate controllers and hydraulic valves. The water passes through the filters under a pressure of over 200 pounds per square inch.

TABLE 3

Turbidity

Untreated water—results in parts per million

YEAR	MAXIMUM	MINIMUM	AVERAGE
1917	300	0	24.8
1918	80	0	8.0
1919	400	0	20.4
1920	400	0	22.3
1921	400	0	25.5
1922	550	0	34.3
1923	500	0	23.8
1924	250	0	27.8
1925	250	0	21.5
1926	160	0	22.5
Average 10 years..	329	0	23.1

The maximum turbidity during this period was 550 parts per million.

TABLE 4

Color

Untreated water—results in parts per million

YEAR	MAXIMUM	MINIMUM	AVERAGE
1917	60	0	8.0
1918	35	0	2.5
1919	45	0	6.1
1920	50	0	6.2
1921	45	0	6.4
1922	48	0	7.2
1923	42	0	5.7
1924	40	0	7.9
1925	40	0	6.8
1926	35	0	6.9
Average 10 years..	44	0	6.4

The maximum color during this period was 60 parts per million.

That these filters handle water similar to that used in the gravity type and produce results comparable with those of the gravity type is seen by the tables showing the quality of the water during the past

ten years. A laboratory is maintained where the water is examined every day.

The filtered water has been practically free from color and turbidity during this entire period.

TABLE 5

Results in parts per million

YEAR	ALKALINITY		HARDNESS	
	Unfiltered	Filtered	Unfiltered	Filtered
1917	71.6	70.4	102.8	107.9
1918	75.8	73.9	109.0	110.3
1919	91.2	88.8	121.3	123.4
1920	95.4	92.0	124.2	126.8
1921	95.6	93.2	125.2	128.4
1922	95.9	94.6	136.0	139.6
1923	96.1	94.1	141.5	144.7
1924	99.0	94.4	159.2	159.5
1925	102.5	98.7	148.9	152.3
1926	104.3	99.9	150.3	153.8
Average 10 years........	92.7	90.0	131.8	134.7

TABLE 6

Number of filters washed and per cent of filtered water used

YEAR	WASHED	PER CENT
1917	1,609	1.50
1918	1,458	1.01
1919	2,017	1.85
1920	2,189	2.15
1921	2,237	2.28
1922	2,979	2.78
1923	3,059	2.72
1924	3,376	3.04
1925	4,331	3.47
1926	5,936	5.03
Average 10 years.........	2,919	2.58

The results in table 5 show that the coagulant reduced the alkalinity an average of 2.7 parts per million and increased the soap hardness 2.9 parts per million.

TABLE 7

Bacteria per cubic centimeter gelatin counts, 20°C. for 48 hours

At various stages of process

YEAR	MAXIMUM	MINIMUM	AVERAGE
		Untreated	
1917	28,400	80	4,970
1918	22,600	80	4,184
1919	56,400	114	4,309
1920	52,400	140	4,771
1921	31,400	120	4,488
1922	28,900	170	3,917
1923	15,000	100	2,222
1924	17,000	300	2,103
1925	14,000	200	2,213
1926	16,200	110	2,137
Average 10 years..	28,230	141	3,540
		Settled	
1917	800	1	10
1918	630	1	14
1919	160	1	13
1920	420	1	21
1921	580	1	14
1922	310	1	14
1923	180	1	10
1924	131	1	8
1925	57	1	6
1926	560	1	11
Average 10 years.	383	1	12
		Filtered	
1917	260	1	5
1918	150	1	6
1919	41	1	4
1920	14	1	2
1921	48	1	2
1922	41	1	3
1923	50	1	2
1924	38	1	2
1925	11	1	2
1926	58	1	2
Average 10 years.	71	1	3

TABLE 8

B. coli-communis, presumptive tests, 1 cc. samples

YEAR	EXAMINED	PRESUMPTIVE	PER CENT
Untreated			
1917	1,095	809	73.89
1918	1,095	803	73.33
1919	1,098	804	73.22
1920	1,095	665	60.73
1921	1,092	644	59.00
1922	1,095	823	75.16
1923	1,098	644	58.65
1924	1,095	656	59.91
1925	1,095	686	62.65
1926	1,095	624	56.99
Average 10 years	1,095	716	65.39
Settled			
1917	1,089	24	2.20
1918	1,095	26	2.37
1919	1,080	53	4.91
1920	1,080	38	3.52
1921	1,080	14	1.30
1922	1,083	39	3.60
1923	1,083	23	2.12
1924	1,074	32	2.98
1925	1,083	28	2.59
1926	1.077	53	4.92
Average 10 years	1.082	33	3.05
Filtered			
1917	1,167	7	0.59
1918	1,095	3	0.27
1919	1,098	11	1.00
1920	1.095	0	0.00
1921	1,092	0	0.00
1922	1,095	0	0.00
1923	1,098	1	0.09
1924	1,095	3	0.27
1925	1,095	0	0.00
1926	1,098	7	0.64
Average 10 years	1,103	3	0.27

The filters are washed with filtered water. Data thereon are shown in table 6.

Recently an elevated wash water tank has been installed. The use of this tank in washing the filters will relieve the previous fluctuation in pressure during the washing periods.

The data in table 7 show that the basins removed an average of 96.66 per cent of the bacteria. The filters removed 75.00 per cent of the bacteria which passed the basins, while the total combined removal was 99.92 per cent of all bacteria.

Table 8 shows that the basin removed an average of 95.34 per cent of the B. coli-communis. The filters removed 91.15 percent of the B. coli-communis that passed the basin, while the total removal for the plant was 99.59 per cent.

The records of the State Board of Health indicate that the districts supplied with this water have been consistently free from typhoid fever outbreaks.

At times there have been odors and tastes due to phenolic wastes. These troubles have been most pronounced when the temperature of the water was low. When they were first noticed many years ago, before our knowledge of phenol flavors had been developed, it was assumed that the trouble was due to algae, as microscopical examinations at such times showed the presence of such organisms as Asterionella and Synedra.

To overcome the flavors due to phenol, potassium permanganate has been added, in small amounts, to the raw water. As far as the writer knows, this is the first plant in this country which has used potassium permanganate for any length of time to relieve such conditions. When potassium permanganate is used it is possible to reduce the amount of liquid chlorine, and the flavors due to the phenolic wastes are eliminated.

From time to time, additional filter units have been added, so that at present the plant contains fourteen pressure units, each 8 feet in diameter and 25 feet long. When operating at a rate of 2 gallons per square foot sand area per minute, the capacity is over 8 million gallons per day.

For years, pressure filters have not been approved by some state officials. Most of the installations of pressure filters have been in small places, where their operation has been neglected, and the results have not been satisfactory. One of the chief objections to

this type filter was the unreliable method for the application of the coagulant. Recently an injector method for the application of the coagulant has been developed to overcome this former criticism, and it is now possible to control the application of the chemicals and produce desired results. Certainly the results obtained at the plant under consideration are equal to results obtained by the use of gravity filters. Filters are machines and unless properly operated will not produce satisfactory results.

PROPOSED CLASSIFICATION OF INDIANA PUBLIC WATER SUPPLIES[1]

By L. S. Finch[2]

In Indiana there are now 249 public water supplies, varying in size from the plant at Kirklin, where the water is pumped by windmill, to the up-to-date plant at Indianapolis. The deepest well from which an Indiana supply is drawn is at New Palestine where there is a 1000-foot flowing well. At this place the water is pumped by hydraulic ram.

Most of the Indiana supplies are taken from tubular wells. In fact 154 of the 249 supplies come from such wells. As shown by table 1, the majority of the well supplies are drawn from tubular wells varying in depth from 100 to 300 feet. There are 72 of this depth.

There are 44 water purification plants in the state, 19 of which practice sedimentation and filtration in gravity filters followed by chlorination. There are, in addition, five supplies which use pressure filters.

SURVEY OF INDIANA PUBLIC WATER SUPPLIES

In the early part of December, 1926, the Water and Sewage Department, by questionnaire, undertook to make a survey of the public water supplies. It would have been more satisfactory to have made personal inspections of the various plants, but, with the personnel available, this was out of the question.

The questionnaires were to have been filled in and returned by January 15, but about 70 have not yet come in. For that reason it will be impossible to include all of the Indiana supplies in this report. In studying the data submitted, it was noticed that certain sanitary defects were found quite often. Table 2 lists those defects which were most prevalent. In considering table 2, it should be borne in

[1] Presented before the Indiana Section meeting, February 18, 1927.

[2] Director, Water and Sewage Department, State Board of Health, Indianapolis, Ind.

mind that each type of defect may not be considered as having an opportunity to occur in all of the 176 supplies surveyed, since part of them apply only to purification plants, of which there are only 44.

Of the above defects, one of the most serious is that where the annular opening between the well casing and the drop pipe or pump

TABLE 1

Public water supplies—source and extent of treatment

	NUMBER	
A. Untreated supplies:		
Tubular wells:		
0–25 feet depth	0	
25–50 feet depth	18	
50–100 feet depth	54	
100–300 feet depth	72	
300 feet and deeper	10	
Dug well:		
0–25 feet depth	7	
25–50 feet depth	11	
Springs, infiltration galleries	6	
Surface water, steams or impounded supplies	11	
Total		189
B. Treated supplies:		
Chlorination only:		
Ground waters	12	
Surface	4	
Filtration only	1	
Sedimentation and chlorination	3	
Sedimentation, pressure filters and chlorination	5	
Sedimentation, filtration and chlorination	19	
Total		44
C. Unclassified:		16
Grand total		249

column is not sealed properly. With this space open, contamination may easily find its way into the well, or, if the opening is closed but not sealed, any water standing in the pump pit, or around the well, may contaminate the drinking water.

Underground and surface contamination from privies, cess pools, etc. is also very dangerous. In the above table of defects such

sources of contamination were located within 300 feet of public wells in 46 cases. Within 300 feet of one public well, at least 25 such sources of contamination are located, and in addition, the annular opening referred to above, is not properly sealed. These wells were about 175 feet deep. Upon examination, the water showed no evidence of bacterial contamination, but did indicate by the chlorides, nitrites and nitrates, that purified sewage was probably reaching the wells.

In each of the above cases, bacterial contamination may be expected to appear in the water at any time, with no one the wiser, unless samples happen to be sent to our laboratory at just the right time. In order to protect the consumers of this water, until such time as the unsatisfactory conditions may be remedied, samples should be submitted at regular and frequent intervals.

TABLE 2

Tabulation of the more common sanitary defects noted in a survey of 176 public water supplies

(Survey made from questionnaire)

DESCRIPTION OF DEFECT	NUMBER OF SUPPLIES AFFECTED
Auxiliary surface water supply (not including treatment by-passes)	7
Sources of contamination located within 300 feet of wells	46
Annular opening between pump column or drop pipe and well casing not sealed satisfactorily	15
Gravity mains of pipe other than cast iron or wrought iron	4
No scales under chlorine cylinders	3
Test for residual chlorine not used	10
Supplies inadequate	13
Well casings under suction	26
Wells, reservoirs, etc. improperly protected	20

CLASSIFICATION OF UNTREATED SUPPLIES

The extent of the danger varies in most cases. For this reason it probably would not be necessary for all the supplies to submit samples at the same interval and it becomes necessary to classify the supplies in order to determine how often samples should be submitted.

In the case of supplies which have no visible defects, routine

samples should also be submitted to guard against possible changing conditions.

In table 3, a tentative classification of untreated public water supplies is listed. This classification has been prepared to aid the department in determining the interval at which samples should be submitted to our laboratory. Under the present conditions, samples are submitted only once each year from untreated supplies. From this one sample we cannot form a reliable opinion concerning the

TABLE 3

Proposed classification of untreated water supplies

CLASSIFICATION	DESCRIPTION
S A	Supplies from tubular wells over 100 feet in depth, wells and distribution system to be free from sanitary defects, and laboratory examinations to indicate supply to be satisfactory
S B	Supplies from tubular wells over 50 feet in depth, wells and distribution system to be free from sanitary defects, and laboratory examinations to indicate supply to be satisfactory
S C	Supplies from tubular wells over 20 feet in depth, wells and distribution system to be free from sanitary defects, and laboratory examinations to indicate supply to be satisfactory
S D	Supplies from dug wells over 20 feet in depth, wells and distribution system to be free from sanitary defects, and laboratory examinations to indicate supply to be satisfactory
S E	Supplies taken from springs, the source and distribution system to be free from sanitary defects, and laboratory examinations to indicate the supply to be satisfactory
U F	Supplies from dug wells under 20 feet in depth, infiltration galleries, etc., source and distribution system to be free from sanitary defects, and laboratory examinations to indicate supply to be satisfactory
U G	Untreated surface water, or ground water supplies which cannot be considered satisfactory at any time

sanitary quality of the water under all conditions. This classification with respect to sampling is not intended to portray the relative safety of the various supplies.

Under the above classification, a supply Classed S A C would be a supply which Classes "A" according to depth and type, but from which, because of sanitary defects, more frequent samples are required, than from Class S A. A supply classified U A F would be a tubular well over 100 feet in depth, but which could not be approved

because of some serious sanitary defects. In this case, samples would be required with the same frequency as from Class U F supplies.

"Drinking Water Standards" published by the United States Public Health Service, gives the following examples of sanitary defects in untreated water supplies:

Caves, sink holes or abandoned borings used for surface drainage or sewage disposal in vicinity of source. Casing of tubular wells, leaky, or not extended to sufficient depth, or not extended above ground or floor of pump room, or not closed at top; or casing improperly used as suction pipe. Collecting well or reservoir subject to backflow or polluted water through improper drain, etc. Source of supply or structures subject to flooding.

TABLE 4

Schedule for submission of samples

UNTREATED	
S A	Semi-annual chemical and bacteriological sample
S B	Semi-annual chemical and bacteriological sample
S C	Annual chemical and bacteriological sample, monthly bacteriological samples
S D	Annual chemical and bacteriological sample, semi-monthly bacteriological samples
S E	Annual chemical and bacteriological sample, weekly bacteriological samples
U F	Annual chemical and bacteriological sample, semi-weekly bacteriological samples
U G	Annual chemical and bacteriological sample

Note: Samples for chemical and bacteriological examination are submitted in iced containers.

Samples for bacteriological examination only are submitted in mailing cases.

Sanitary defects of distribution systems (applying both to treated and untreated supplies) are listed as follows:

Existence of cross connections between the primary supply and secondary supply of unsafe quality.

Return to the system of any water used for cooling, hydraulic operations, etc.

Inadequate protection of distribution reservoir.

Intermittent service, resulting in reduced or negative pressures in distribution system.

New connections of pipe lines joined to a system without prior disinfection of pipes.

Existence of tile or other leaky pipe in distrubution system.

TABLE 5

Proposed classification of treated water supplies

CLASSIFICATION	DESCRIPTIONS
S 1	Adequately treated supplies, without sanitary defects, with a raw water not grossly polluted, with complete laboratory control by technically trained and experienced men
S 2	Adequately treated supplies with a raw water not grossly polluted, without sanitary defects in the distribution system, and with complete laboratory control by experienced men without technical training
S 3	Adequately treated supplies, with a raw water not grossly polluted and without sanitary defects in the distribution system, with incomplete laboratory control
S 4	Adequately treated supplies, with a raw water not grossly contamined, with no laboratory control and without sanitary defects in the distribution system
S 5	Inadequately treated supplies, with complete laboratory control. With a raw water not grossly polluted, and without sanitary defects in the distribution system
S 6	Inadequately treated supplies, with a raw water not grossly polluted, and without sanitary defects in the distribution system, with incomplete laboratory control
U 7	Inadequately treated supplies, with a raw water not grossly polluted, and without sanitary defects in the distribution system, with no laboratory control
U 8	Treated water supplies which are considered to be unsafe to drink at all times

TABLE 6

Schedule for submission of samples

CLASSIFICATION—TREATED	SAMPLES REQUIRED
S I	Annual sample
S II	Monthly bacteriological samples
S III	Semi-monthly bacteriological samples
S IV	Weekly bacteriological samples
S V	Annual sample
S VI	Weekly bacteriological samples
U VII	Semi-weekly bacteriological samples
U VIII	Annual sample

Pumping station defects are listed as follows:

Leaky suction pipe.
Suction well unprotected from surface or subsurface pollution
Suction well subject to pollution through backflow of polluted water through drain.

SUBMISSION OF SAMPLES

In table 4, a schedule is given for the submission of samples from supplies of the various classes.

TREATED WATER SUPPLIES

In considering treated water supplies, as in the case of untreated waters, the same necessity exists for the submission of samples at varied intervals. In table 5, the classes of treated waters are drawn with respect to adequacy of treatment, efficiency of laboratory control and the absence of sanitary defects.

As in the case of the untreated classification, a supply classed S 1, 3, would be a supply which classes 1 according to adequacy of treatment and control, but from which, because of sanitary defects or grossly contaminated raw water, more frequent samples are required.

Class S 1 A would be a supply which serves the public with Class S 1 treated water and also with untreated well water from tubular wells 100 feet and over in depth which rate Class S A.

In the case of treated water supplies, sanitary defects include:

Existence of by-passes through which unfiltered water may be delivered to the distribution system without the proper supervision.
Inadequacy of works, necessitating overloading or by-passing.
Inadequate protection of purified water.

SUBMISSION OF SAMPLES

Table 6 fixes a schedule for the submission of samples from supplies of the various classes.

CERTIFICATION

Those supplies which take the necessary steps to insure their patrons satisfactory water at all times, should receive some sort of recognition for their efforts. With this idea in mind, the Water and Sewage Department, Division of Chemistry, of the Indiana State

Board of Health is prepared to issue certificates of approval in accordance with the following rules.

TENTATIVE RULES FOR CERTIFICATION OF INDIANA PUBLIC WATER SUPPLIES

Those public water supplies, Class S E or higher and Class S 6 or higher, which comply with the following rules may be certified.

1. Submission of samples as required from respective classes.
2. Compliance with Water Analysis Act of 1919.
3. Submission of Weekly Chemical Pumpage Reports where required by order of the Indiana State Board of Health promulgated in October 1917.

FLOW TESTS ON FIRE HYDRANTS[1]

By R. C. Stange[2]

In the reports which the National Board of Fire Underwriters issues on the fire-fighting facilities of the various cities of the United States, one of the most important items is an estimate of the amount of water available for fire protection, in excess of the normal demands of domestic consumption. At the time the issuing of these fire protection reports was inaugurated, no practical method had been devised of measuring this flow. Calculations could be made in some instances, but in a well gridironed system these became much involved and in addition necessitated the making of assumptions which were likely to produce misleading results.

The present method of conducting flow tests, as practiced by engineers of the National Board and also by nearly all insurance rating organizations, is a development of the method of measuring discharges from fire department nozzles by means of a Pitot tube and gauge, originated by John R. Freeman and used in various other ways, such as the testing of fire department pumpers. It is possible to measure discharges from hydrants with a considerable degree of accuracy by the same method used in testing fire engines, that is by the use of short lengths of hose and large smooth-bore nozzles. However, this scheme would necessitate much time, labor and equipment, and in distribution systems where the normal pressure carried is low, only a small part of the total quantity available for engine supply may be obtained in this manner. For these reasons and in order that a number of representative tests might be made in a reasonable time and with a reasonable number of men, the present system of measuring discharges from open hydrant outlets was worked out.

The equipment necessary consists of a hydrant cap tapped out to take a pressure gauge, four Pitot blades, four 50-pound gauges and a 200-pound gauge. The Pitot tube ordinarily used is a straight

[1] Presented before the California Section meeting, October 6, 1927.

[2] Engineer, National Board of Fire Underwriters, San Francisco, Calif.

blade about 4 inches long, threaded to connect to a piece of quarter-inch brass pipe a few inches long, on the other end of which is screwed the 50-pound gauge by which the velocity of discharge is determined. A union may be used to allow a change in the relative position of Pitot blade and gauge dial.

The gauge best suited for the purpose is graduated in half pounds, from 0 to 50 pounds, which may easily be read to the nearest quarter pound. Gauges of such a small maximum reading should be calibrated by means of a weight tester or reliable test gauge before being used, as they are more sensitive to rough handling than gauges designed for higher pressures. Gauges without pin at zero are recommended.

In making flow tests, it is preferable to use $2\frac{1}{2}$-inch hose outlets rather than 4- or $4\frac{1}{2}$-inch steamer connections, for in the latter the orifice is often not completely filled or the velocity of discharge is not uniform throughout the entire area. Neither of these disadvantages is so marked in the smaller outlets and may usually be ignored entirely. The area of no flow is almost always a segment of varying height in the bottom of the outlet; this height may be estimated by the observer by using the Pitot blade or a rule. In most cases the "hole" or area of no flow is fairly well defined and its proportion to the area of the entire outlet may be calculated. Where the pressure is insufficient to fill the outlet to the top, measurement of the depth of water flowing is sufficient to determine the discharge.

Velocity heads of from 2 to 20 pounds are desirable, as they are read with greater accuracy. For very low velocities an error in the gauge reading has a greater relative effect, and for high velocities there is likely to be much fluctuation. The observer will soon train himself to estimate an average velocity by moving the Pitot tube across the stream; ordinarily for $2\frac{1}{2}$-inch outlets the center reading will be substantially the average. Close to the sides of the outlet there is a retardation of flow, to take account of which a coefficient of discharge is applied to the theoretical quantity corresponding to the indicated velocity. This coefficient has been determined for three makes of hydrants, with outlets of different sizes and with various velocities of discharge. The discharges as measured by Pitot tube at the outlet were compared with those determined by Venturi meter, pitometer and current meter. In these experiments the coefficient of discharge varied from 0.85 to 0.96 with an average

of 0.91; a coefficient of 0.90 was employed in computing the tables used by the National Board.

The pressure in the mains before and during the test, is noted by a gauge attached to a hydrant which is preferably in the center of the group of hydrants opened. Knowing the loss of head due to ordinary consumption demands and the additional loss due to a measured flow from hydrants, the quantity available for any other given loss may be closely approximated.

The number of hydrants opened in an individual test depends largely upon the strength of the distribution system. In a well gridironed system, 4 are ordinarily used. The object is to draw enough water to lower the pressure in the mains by 10 to 20 pounds, which is sufficient to insure accuracy in estimates of flow available at lower residual pressures. Rarely does the number need to exceed 4, except in distribution systems of exceptional strength. The lay-out of the test, of course, varies according to the character of the system. Particular attention should be paid to the location of the residual pressure gauge in order that it may represent a true average pressure in the mains when the hydrants are open. One hydrant opened each way from the residual gauge is considered ideal.

Effort should be made to simulate actual fire conditions as much as possible. The ordinary fire department pumper is usually of 750 or 1000 gallons a minute capacity and this is considered a reasonable flow per hydrant. With two hose outlets open, this quantity gives a gauge reading within the most accurate range. Larger flows may produce erroneous local friction losses.

For making flow tests, the California type hydrant in common use on the Pacific coast is the hardest to handle. Having the valve directly at the outlet, it is necessary to open the hydrant wide to produce as smooth a stream as possible. With high initial pressures, discharge readings too high for accurate measurement are obtained in this manner and there is, in addition, the danger of wetting down adjoining property from the spraying produced as the hydrant is first opened. The latter drawback may be reduced somewhat by using short pipes on the outlets, made by leading a 12- or 15-inch length of 2½-inch pipe to an ordinary hose coupling. In extreme cases it may be necessary to shut the gate-valve in the hydrant branch open the hydrant outlets wide and then control the flow by means of the gate valve. For all other standard makes of hydrants, the opening of the hydrant may be controlled to give the desired flow.

Hydrants in the group are opened simultaneously and, as soon as the rate of flow is steady, as shown by the residual pressure gauge, a reading is taken on each discharging outlet. Operators should be cautioned to shut down slowly as the flow of the group is greater than that drawn in the flushing of a single hydrant, with consequent greater water ram, unless these precautions are observed. Care should also be taken to keep the hydrants open long enough to allow the residual gauge to settle down to a steady reading; the initial drop in pressure as the hydrants are first opened will always be greater than when the surging has settled down and the flow has become steady.

With a definite drop in pressure thus obtained for a known quantity of water flowing, the quantity available at any residual pressure is readily estimated by using the Hazen-Williams hydraulic slide rule. This method will answer for most tests, but cannot be used where the assumed residual pressure would lower the hydraulic gradient below any high point of the main between the source of supply and the test. Approximate results may be obtained with an ordinary slide rule.

In analyzing results of tests, actual conditions prevailing at the time of a serious fire should be taken into consideration. For instance, an elevated tank of small capacity near the test will result in an unduly high rate of flow which can not be maintained when the tank has been emptied. In cases of this kind the test is best run with the tank shut off.

Tests should be made at representative points in the distribution system. Some should be made on the main arteries, to determine their adequacy, and others on minor distributors to study local losses. Aside from their use as a direct measure of the water available for fire protection, the tests may be of value to the water works engineer in other respects. They indicate the presence of obstructions in the mains, such as closed valves, and show the reduced carrying capacities of mains due to tuberculation or incrustation. As they show the effects of a known draft, they furnish data to calculate the effect of any demand and may profitably be employed in designing reinforcements to the distribution system.

MODERN ASPECTS OF CHLORINATION OF WATER[1]

By Norman J. Howard[2]

In presenting this paper the writer's object is to offer a brief discussion, non-technical in character, containing a résumé of the progress in the treatment of water by means of chlorine.

Since the first practical application of chlorine to water at Lincoln, England, in 1905 by Sir Alexander Houston considerable advances have been made. The early application was composed of a commercial product called "Chloros" which consisted of an alkaline solution of sodium hypochlorite containing from 10 to 15 per cent of available chlorine. This was followed by Johnson in 1908 at Chicago when calcium hypochlorite, commonly known as bleaching powder, was used. Following the research work of Darnall in 1910, who demonstrated the practicability of using chlorine in gaseous form, the use of liquid chlorine extended, and in 1913 new and greatly improved equipment was put on the market resulting in the general use of gaseous chlorine in an aqueous solution. Since that time each year has shown fresh advances in application and use, both in Europe and America.

Our early conception as to the germicidal properties of chlorine in water were based upon a study of hydrolysis, which resulted in the decomposition of hypochlorous acid and the liberation of nascent oxygen known to have marked oxidizing properties. The results of recent researches have more or less disproved this theory and J. C. Baker has suggested that the sterilizing action of chlorine in water is not due to direct oxidation by the chlorine, but to the formation of some substance toxic to bacteria which interferes with further cell division, thereby stopping multiplication and resulting in the death of the organisms.

[1] Presented before the Canadian Section meeting, March, 1927.

[2] Bacteriologist-in-charge, Water Purification, Island Filtration Laboratories, Toronto, Can.

CHLORINE

In the early days of treatment, chlorine was used either as the final adjunct in a water purification process or as a straight sterilizing reagent to water partially purified or water receiving no other treatment. Apart from general considerations many were opposed to the use of chlorine in water, claiming that the construction of purification works would be delayed so long as a safe water could be procured without filtration. Modern conditions however demand not only a safe water, but also a physically good supply. Rapid progress in construction of water purification plants in all parts of the world would seem to bear out this contention.

The application of chlorine to water is not now confined to sterilization, but its use is being extended for various purposes. The prechlorination process which consists of applying chlorine to water before filtration was reported upon by Weston and Howard, the City of Toronto adopting the treatment in 1921. At the present time, according to C. R. Cox, a large number of cities in America are now using this method. The process has many advantages, the chief consideration being an economic one. At London, England, Sir Alexander Houston has used prechlorination for several years past. The practice was introduced as a war measure after it had been demonstrated that the application of limited amounts of chlorine to the Raw Thames River Water, would furnish a safe and favorable substitute for prolonged storage in the Staines Reservoirs. The water after treatment flows several miles through open aqueducts before passing through slow sand filters. All the chlorine is however used up long before the water reaches the filters. By eliminating double pumpage the estimated saving effected during 1925 was in excess of $50,000.

In Toronto, by substituting chlorine for alum at such times as the raw water was physically good, maintenance costs of the drifting sand filters have been reduced by $150,000 over a period of four years. It seems quite unnecessary to apply large doses of alum to a physically good water, when increased bacterial efficiencies can be secured by small doses of chlorine at a fraction of the cost. Some criticism has been made of the use of the prechlorination process. In view of the fact that extensive experimental work has been carried out by several State Boards of Health, resulting in its use in some twenty cities in America, the criticism can hardly be said to be justi-

fied. Chief objection has been based upon the claim that chlorine interferes with the filtration process, by destroying the surface sand coating. Experimental studies carried out in Toronto showed that, when moderate doses of chlorine were applied, the film on the sand grains was not affected. The film consists of colloidal and organic matter, and when tested showed that the sand grains had absorbed alumina hydroxide which remained on the sand for several weeks regardless of whether alum was applied or not. It was further noted that, in moderately turbid water, considerable economy in alum could be effected by applying small doses of chlorine and reducing the alum to a dose just sufficient to produce clarification. C. R. Cox of the New York State Department of Health has recently reported that prechlorination aids coagulation due to the effect of chlorine on organic matter in the raw water, so that the physical state of the stabilizing protective organic colloids is altered, or that the organic matter is "aged" by the chlorine through the formation of saturated compounds. Our observations in Toronto carried out by Frank Hannan over a period of five years certainly confirm the views of Cox. The clarification of the water when using chlorine with alum is, if anything, greater than when using alum alone. It is now universally conceded that water of certain hydrogen-ion concentrations, after treatment with alum, will pass decomposed alum in colloidal form. The amount of this has been reliably estimated by Hatfield and Hannan and approximates a maximum of one-fifth part of one in a million parts in the Great Lakes water. There is no evidence that prechlorination increases the residual colloidal alumina. Theoretical considerations indicate that as increased doses of chlorine raise the hydrogen-ion concentration of the water, the amount of residual alum would actually be decreased to a small extent. Other advantages of prechlorination are reduction of filter loading in heavily polluted water, increased rates of filtration, reduced operating costs and an added safeguard in water subject to rapid periodic changes in quality.

Increasing attention is being given to the treatment of water with chlorine for the destruction and prevention of algal growths in filter underdrains, sedimentation basins and for the sterilization of new water mains. For many years past copper sulphate has been used for the destruction of algae and while it still remains the best for treatment of reservoirs and impounding basins, chlorine is preferable for some other conditions. The application of chlorine to the raw

water at Newport News, Va., has been completely successful in preventing algal growths on the walls of the filters, while in Illinois excessive growths of crenothrix in the filter beds and underdrains were destroyed by chlorination. Under such circumstances it should be pointed out that it is necessary to retain a definite amount of chlorine in the filters for a predetermined period. Chlorination has been successfully practiced for the destruction of growths in filter underdrains in both Europe and America. Excess chlorine was unsuccessfully tried in Toronto on the slow sand plant in an endeavour to lengthen filter runs. For practically two months in the spring of each year the waters of the Great Lakes are affected by some condition, which is usually accompanied by a considerable increase in the microscopic content. The effect of this is to build up rapidly the loss of head and increase resistance to the passage of water through the filters. The microscopic content is partly involved, but as similar numbers of organisms frequently occur throughout the summer months without seriously affecting the loss of head, it is obvious that some other factor also plays a part. Excess chlorine was applied to remedy this condition and later copper sulphate was tried, but neither improved the situation at all. The sterilization of new water mains is extending in all parts of America, and it is probable that in the near future this practice may be made compulsory. The annual report of Sir Alexander Houston on the London supply for the year 1925 gave details of the successful chlorination of a house service which had become infected with small worms. Practically all swimming pools are now treated with chlorine and a definite excess of chlorine has to be maintained in the water. In New York and elsewhere chlorine in large doses has been used to destroy taste caused by excessive growths of microscopic organisms. It is not known definitely if the excess chlorine oxidizes the taste-producing matter or forms a tasteless substitution compound. In view of recent work along other lines it seems probable that the latter consideration is most likely involved.

CHLORAMINE COMPOUNDS

The use of chloramine and dichloramine which consist of a mixture of chlorine and ammonia was first used in the treatment of water at Ottawa, Ont., by J. Race in 1917. The most effective dose of chloramine has been found to be four parts of chlorine to one part of ammonia. Much research work has been carried out recently in Eng-

land on this substance chiefly by Major C. H. Harold and Sir Alexander Houston. It possesses certain advantages over straight chlorine and is said not to cause any taste in the treated water. While laboratory work is being carried out at Toronto, there are no figures available showing that taste will not result in water polluted with industrial and other waste matters. Chloramine has great sterilizing properties although the immediate effect is slower than chlorine alone, but it has the added advantage that it possesses certain potential sterilizing powers not possessed by chlorine. In cities troubled with aftergrowths in the mains or troublesome sporeforming bacteria the use of chloramine has great possibilities. In waters where high doses are applied, economy might be effected by using chloramine. The writer does not know of any installation where chlorine and ammonia are being jointly applied in gaseous form. The first practical application in America of ammonia and chlorine to water for the elimination of taste, was made quite recently at Greenville, Tenn. by J. W. McAmis. For a considerable time past an iodoform taste was experienced in the water after chlorination. By adding 0.35 part per million of ammonia (NH) to the raw water ahead of coagulation, and applying chlorine in the coagulating basin prior to filtration, taste has been completely overcome. McAmis advises that each time the ammonia treatment is discontinued taste reappears.

SUPERCHLORINATION

Probably by far the most important question of the present day, is that of taste following the application of chlorine to water. This condition may be said to be world-wide in extent and while in many cases the reasons are known, there are probably a great many instances where the cause is a matter of conjecture. It is strange however that while chlorine is the direct cause of taste, this same reagent may be effectively used to destroy taste-forming substances. Generally speaking the worst taste occurring in chlorinated water is caused by small doses of chlorine. By slightly increasing the chlorine beyond the taste-producing dose, the conditions become worse, but beyond a certain figure which in all cases must be determined the taste improves and subsequently disappears. It is perhaps unfortunate that the taste zone is very close to the normal dose of chlorine applied in many cities and towns, thus explaining the frequency of taste in many localities. It is not within the province of this paper to discuss the causes of taste in water. The subject has recently been covered by the writer elsewhere but it

may be of interest to point out that taste can be divided into two groupings. The first is the taste caused by an excess of chlorine due to overdosing and the second is a distinct chemical taste resembling iodoform. The cause of this latter condition is due to the formation of substitution compounds, the chlorine acting upon either, substances of unknown origin, organic matter or upon industrial wastes containing coal tar derivatives. Taste due to excess chlorine alone can be remedied by controlling the dose according to accepted practice, but the treatment of the chemical taste in water is one involving a study of the actual causes and determining the most suitable method for counteracting the condition. Recent researches carried out on behalf of the City of Toronto by Howard and Thompson have thrown considerable light on the subject of taste prevention. The outcome of this work was the adoption of a superchlorination and dechlorination method. It should be pointed out that while the treatment by excess chlorine was reported upon by Sir Alexander Houston in England, the first large application was successfully carried out in Toronto, where over 70 million gallons of water were treated daily for a period of three months. Exhaustive experimental work was carried out over a period of three years and much new information as to the controlling factors was reported. It was ascertained that the amount of excess chlorine required to destroy taste was directly proportionate to the amount of taste-producing matter present and that a definite time contact period was necessary. Too little chlorine or insufficient time contact renders the treatment ineffective. Regardless of the nature of the taste-producing matter present the experimental work demonstrated the effectiveness of the superchlorination method. In Toronto 12.5 pounds of chlorine per million gallons of water were applied and after $1\frac{1}{4}$ hours contact, the residual chlorine amounting to approximately 4 to 6 pounds was removed by sulphur dioxide which was applied through vacuum pedestal machines. Some of the conclusions reached as a result of the Toronto work were as follows:

1. While phenol is contributory to the production of taste there are also other causes of unknown origin.

2. Decomposing organic matter may form phenoloid bodies and cause taste in chlorinated water.

3. Of a large group of substances examined derived from the destructive distillation of coal phenol, cresol, anisole and xylenol produced an iodoform taste and odor in the presence of free chlorine.

4. The formation of substitution compounds causing taste in chlorinated water may be prevented by the excess chlorine and dechlorination method.

5. Definite time contact periods are necessary for varying doses of taste-producing substances to effect their destruction. Such contact period may be shortened by greatly increasing the chlorine dosage.

6. Under heavy discharge conditions sulphur dioxide requires considerably more heat than chlorine to maintain cylinder pressure.

7. The effective chlorine dosage to destroy taste must be separately determined on each supply involved.

In the fall of the year it was noticed that slight taste developed following the superchlorination treatment which resulted in further experimental work being carried out. It was found that, with a drop in water temperature below 42°C., greatly increased applications of chlorine became necessary, the effective dose increasing to 2 parts per million for the mechanically filtered water and 1.5 parts per million for the slow sand filtered water. Operating conditions have clearly shown that some other factor interferes with the effectiveness of the treatment under cold water conditions. Residual chlorine studies showed that this condition was seemingly not involved, actually the figures indicated a decreased rate of chlorine absorption and a necessary increase of sulphur dioxide for complete removal of excess chlorine. It seems highly probable that the decreased biological activity in the cold water prevents the natural destruction or reduction of phenolic bodies in the raw water. Consequently the phenolic concentration is greater and a larger amount of chlorine is required. When using excess chlorine the practice of prechlorination was abandoned as it was found to interfere seriously with taste destruction. After thirty minutes contact in the mechanical filters the residual chlorine was so reduced in quantity that an insufficient amount remained. As it was found impossible to regulate the dose to meet varying conditions the treatment was discontinued. In testing superchlorinated water for residual chlorine under cold water conditions, at least ten minutes contact with *orthotolidin* solution is necessary to insure correct readings. Improvement in maintaining pressure of liquid sulphur dioxide under high discharge conditions has been effected by placing steam coils between the cylinders.

In conclusion, one observation made at Toronto should be mentioned. This has reference to the determination of free chlorine by the orthotolidin method and is of considerable importance. It was found that sunlight seriously interfered with the production of color, and if correct results are desired samples of water being tested should be protected from sunlight when the orthotolidin solution is added, otherwise an error as high as 70 per cent may be recorded.

REPORT OF COMMITTEE NO. 1 ON STANDARD METHODS OF WATER ANALYSIS[1]

Committee No. 1 has concerned itself with certain improvements in the bacteriological and chemical examination of water during the current year, as in past years. Among the items which have received the greatest amount of attention are the following:

1. The use of brilliant green lactose bile medium as a secondary fermentation medium in the detection of organisms of the colon group of bacteria. Earlier experience with this medium as a primary fermentation medium was not entirely satisfactory throughout the country, as some coli-form organisms were inhibited. Preliminary tests, however, have indicated that the medium would be of special value, if material taken from positive lactose tubes were inoculated into brilliant green lactose bile media. A high percentage of positive confirmations followed this practice and corresponded well with the results of the standard completed confirmation. In view of the great saving in time which could be made if secondary confirmation tests were not necessary, a portion of the work of Committee No. 1 has been devoted to an attempt to improve the existing formula for brilliant green lactose bile medium in such a way as to reduce the inhibitory effect of the medium when used as a primary fermentation medium. Any practice which will make easier and speedier the detection of organisms of the colon group and their partial confirmation in laboratories not supplied with highly trained personnel will enable these laboratories to give better service and to make more prompt changes in the treatment of water supplies when such changes are indicated.

2. The detection of phenols. These substances are annoying in connection with taste development following chlorination, and the amount which is necessary to produce offensive tastes is surprisingly small. Easy, rapid and certain methods of estimating phenols present in raw water must be developed for detecting and estimating very small quantities of the material sought.

[1] Presented before the Chicago Convention, June 10, 1927. Approved by The Standardization Council.

3. The determination of iodine. In goitre surveys it has been found desirable to estimate iodine ordinarily present in very small quantities. It is desirable to find methods which will not necessitate the handling of large volumes of water but will enable the analyst to estimate minute traces of this important substance. Present methods involve evaporation of 50 to 100 liters of the water being examined.

4. The ortho-tolidine test for free chlorine is a most useful agent in adjusting the dose of chlorine in water purification plants. While the test is easily carried through as specified at present a number of interfering factors deserve special attention. At times certain colors, different from those ordinarily expected in the test, are produced. Work by Mr. Enslow, then of the Virginia State Department of Health, when a member of Committee No. 1, showed that these tests giving abnormal colors were due to certain minor errors of technique. Traces of the reagent or smaller quantities of the material seemed in certain instances to produce blue colors. The influence of chlorates, manganese compounds and the hydrogen ion concentration of the solution in which the test is made, all need further study. It seems especially desirable to have as acid a solution of the ortho-tolidine reagent as is feasible. In the work carried out by Dr. Buswell and Dr. Boruff, as noted in last year's report of Committee No. 1, the difficulty is shown of securing a highly acid solution of the reagent.

Studies on the nitrogen determinations, on microscopic examination of water with the Foerst centrifuge and of soap solutions used in determinations of hardness have been conducted by the referees of Committee No. 1. Minor investigations also have been made in connection with the introduction of proposed media. One of the proposed bacteriological media which has received attention is an erythrosine methylene blue agar devised by Dr. A. J. Salle of California. In addition to erythrosine and methylene blue, Dr. Salle uses the indicator brom cresol purple.

The work on free carbon dioxide and dissolved oxygen in water on which Committee No. 1 has formerly spent much time has been temporarily suspended in order that arrangements can be made to work coöperatively with Mr. Farmer's Sub-committee No. 8 of the general committee on Boiler Feed Water Studies under Mr. S. T. Powell.

The detailed report of the work of Committee No. 1 follows.

BACTERIOLOGICAL METHODS

The composition of brilliant green lactose peptone bile medium, Mr. H. G. Dunham, Referee

Mr. Dunham prepared and published in the magazine "Stain Technology" for October, 1926 (Vol. 1, 129–134) a paper giving a summary of the work on the brilliant green bile medium. This paper is practically the same as that read at the Forty-sixth annual convention of the American Water Works Association in Buffalo, bringing the matter more fully up to date. A reply to the paper has been written by Dr. Hale, of New York City, in which Dr. Hale objected to some of the conclusions drawn by the workers of Committee No. 1. Mr. Dunham replied to Dr. Hale's criticism. Both Dr. Hale's paper and the reply thereto appeared in Stain Technology, Vol. II, No. 1, (January 1927) pages 24–25 and 26. In the study of the composition of brilliant green bile medium Drs. Max Levine, John F. Norton and S. A. Koser, have assisted Mr. Dunham. The Digestive Ferments Company, with which Mr. Dunham is connected, has been of great assistance to Committee No. 1 in the study of these types of media. They have prepared special lots of media which could be supplied to the members of the sub-group and thus enabled all members working upon the medium to use identical preparations. A summary of the results of the investigations on the composition of the medium thus far carried out appears below:

1. Evaporated bile may inhibit or stimulate growth of members of the colon group of bacteria, depending on concentration and reaction.

2. Different samples of bile varied in their inhibitory or stimulating effects. One sample of bile was distinctly inhibitory when employed in 5.0 per cent concentration, while another accelerated growth.

3. With all samples of bile employed, a concentration of 2.0 per cent bile was found to stimulate growth.

4. In an alkaline reaction (pH 7.3 to 7.8) 5.0 per cent bile decreased the generation time (i.e. stimulated growth) while at pH 6.1 the same sample effected retardation of growth.

5. The optimum reaction for growth of *Bacterium coli* is a function of the composition of the medium. Thus in peptone lactose media without bile growth was best at pH 6.1 whereas in peptone lactose bile, optimum growth was obtained at pH 7.3 to 7.8.

6. The amount of brilliant green giving satisfactory results in bile

media was proportional to the bile concentration. With 2.0 per cent evaporated bile, concentrations of dye over 1:50,000 were found to be inhibitory. With 5.0 per cent bile, a concentration of 1:20,000 brilliant green gave very good growth.

Non-confirming spore formers and their significance in water examination, Mr. Norman J. Howard and Dr. John F. Norton, Referees

It has been suggested by Dr. Norton that the following points should be studied during the coming year. A considerable number of cultures of lactose-fermenting, non-confirming organisms have already been collected by Mr. Howard and these should be available for further tests.

1. Work so far indicates that lactose-fermenting, spore-forming organisms are more frequently found in animal excreta than in human, but studies on the latter are relatively few in number. It is desirable to make a somewhat extensive investigation on this point.
2. Studies of the resistance of these organisms to chlorination, particularly of the resistance of spores.
3. The extent to which these organisms are actually interfering with presumptive tests for Bacterium coli.
4. The speed of sporulation and its influence on the microscopic examination for spores should be studied.

The use of brilliant green bile and media containing other tri-phenyl methane dyes as secondary fermentation media in the determination of the Bacterium coli group, Mr. Harry E. Jordan, Referee

The work done prior to last year was summarized by Dunham, McCrady and Jordan and published in the Journal of the American Water Works Association, Vol. 14, No. 6, 535–549, December, 1925. Further study on bile and brilliant green concentration was required before certain peculiarities in performance could be expected to be eliminated.

The work has been admirably carried on by Dunham and Levine, with their associates.

The discussion at the Buffalo meeting did much to produce a sufficiently clarified viewpoint to justify the distribution of material to a group of plant laboratories where the value of the interpolation

of brilliant green bile following original fermentation in lactose broth could be studied.

During the current year Mr. Jordan and his co-workers have carried out a series of tests on two of the recommended formulae for brilliant green lactose bile medium. The media were adjusted to a pH of 7.1 to 7.4 and their variation in bile and brilliant green was as follows: (1) 5 per cent bile with 1:20,000 brilliant green; (2) 2 per cent bile with 1:75,000 brilliant green.

The plan of the work of the collaborators included several essential points and in order to assure adherence to a uniform plan special instruction sheets were supplied. The outline of the procedure was as follows:

1. Colon group—complete confirmation according to Standard Method of Water Analysis, A. P. H. A. and A. W. W. A., 1925.
2. Colon group confirmation according to the completed confirmation procedure Standard Methods 1925, except that 5 per cent brilliant green bile is used for original or primary planting instead of standard lactose broth.
3. Colon group confirmation according to completed confirmation procedure of Standard Methods 1925, except that 2 per cent brilliant green bile is used for original or primary planting instead of standard lactose broth.
4. Colon group confirmation according to the completed confirmation procedure of Standard Methods, 1925, except that from a tube of standard lactose broth used as an original planting medium in which gas has occurred—a loopful of the active growth is to be transferred to a fermentation tube containing 5 per cent brilliant green bile and confirmation of any gas-forming organisms in the bile tube carried through according to the standard completed confirmation from this point.
5. Same as (4) except that 2 per cent brilliant green bile is to be used instead of 5 per cent bile.

In the conduct of the investigations the referee was assisted by Armstrong, of Omaha; Berry, of Columbus; Billings, of Grand Rapids; Butterfield (U. S. P. H. S.), of Cincinnati; Howard and Thompson, of Toronto; Kershaw and Taylor, of Indianapolis, Lauter, of Washington; Mahlie, of Fort Worth; Marshall, of Lansing; McCrady, of Montreal; Nyhan and Gorman, of Chicago; Raab, of Minneapolis; Rider and Stroud, of Tuscon; Stevenson and Herb, of Sacramento; and Wallace, of Detroit.

The referee submits the following conclusions with regard to the experimental work:

1. The 2 per cent bile is slightly superior to the 5 per cent, both when used as the material in which to plant water samples direct as

well as a subcultural medium. In both cases the relation between completions according to Standard Methods and the 2 per cent bile is higher than when the 5 per cent bile is used. The superiority is so slight as to leave the decision as to the density subject to other conditions.

2. When the bile was used as a direct planting medium, the percentage of original fermentation checks with the previous studies of the committee, but the 2 per cent bile shows a slightly higher degree of completion.

3. When the bile was used as a direct planting medium, no cultures were discarded because of the presence of spore forming organisms.

4. When the bile is used as a second step in a subcultural series, the degree of completion on the better bile density is 95 per cent.

5. In three cases out of 1487 cultures, the presence of spores was noted by the worker and used as a basis of rejecting the completion. This is a frequency of 0.2 per cent and appears to be unimportant.

The following conclusions may be drawn from this and the former study on brilliant green bile as a confirmatory medium:

1. The use of brilliant green bile as a secondary planting medium will result in the finding of a reasonably true number of the organisms of the colon aerogenes group if the test be carried to completion.

2. The use of lactose broth fermentation followed by brilliant green bile fermentation should be permitted as an optional procedure in place of the present broth—plate method of evaluating "Confirmed" colon-aerogenes group.

3. The public health official and plant operator will be afforded a very useful method of rapidly evaluating the quality of water samples, if the standard methods suggest the parallel planting of samples in brilliant green bile and lactose broth. Fermentation of the two is very significant. Fermentation of the latter is not. The parallel planting method has been studied by Young, Ritter, and others. Laboratory technicians and plant operators, who use it, value it highly and it should be given proper recognition in standard methods.

4. The completed test for colon-aerogenes group should be rewritten in the light of data concerning synergism and it should be made a more definitely pure culture method than now is the case.

The Chairman of Committee No. 1 has also conducted a considerable number of tests on routine water samples received at the Water Laboratory Division of the State Hygienic Laboratory at the

University of Iowa. This work has shown a very high degree of correlation between the eosine methylene blue agar streaks and the secondary planting into brilliant green lactose bile. Of course, the brilliant green bile medium does not attempt to differentiate between Bacterium aerogenes types of organisms and those of the Bacterium coli type as the eosine methylene blue agar does. In judging the results of the examination the sum of the numbers of tubes found to contain either the Bacterium coli or the Bacterium aerogenes type of organism, or both types, was compared with the number of fermentations which yielded positive results when material from positive lactose broth fermentations was transferred to brilliant green lactose peptone bile. Of 6,188 positive lactose broth fermentations about 80 per cent were confirmed in both cases. The actual figures were 77.4 per cent confirmed in eosine methylene blue agar plates, 75.7 per cent confirmed in brilliant green bile.

The use of eosine methylene blue agar and modifications in the confirmation of organisms of the colon group, Dr. Max Levine, Referee

Dr. Levine has devoted his energy largely to coöperating with Mr. Dunham on the composition of brilliant green bile during the current year. A certain amount of study has been given to a modification of eosine methylene blue agar which has recently been proposed by Dr. A. J. Salle of the University of California. Dr. Salle's medium differs primarily from the Levine modification of the eosine methylene blue agar of Holt, Harris, and Teague, in that erythrosine has been substituted for eosine in the medium and an indicator, brom cresol purple, has been added to the medium in order to show the change in the reaction of the medium under the influence of growing colonies. Preliminary experiments carried out on Salle's medium were not favorable, but additional work using dyes similar to those used by Dr. A. J. Salle in his original work, has shown the medium to be more satisfactory than was at first supposed. Whether or not this medium will be the subject of further study by Committee No. 1 will depend on other tests now under way.

The use of brilliant green bile as a primary medium in the detection of organism of the colon group, Mr. MacHarvey McCrady, Referee

Mr. McCrady has been seriously handicapped in his work this year on account of moving his laboratory to a new location and on account

of the illness of members of the staff. In addition, the city of Montreal, where he is located, has suffered from an extensive milk borne typhoid fever epidemic requiring the attention of the laboratory to the problems connected with this matter. Mr. McCrady, however, has been able to coöperate with Mr. Jordan on the subject under the latter's direction. It will be remembered that the study of brilliant green bile medium as a primary medium for the detection of organisms of the colon group was very extensively studied by the committee a few years ago. It appeared that the medium as then existing was too inhibitory in its action on many organisms of the colon group. Pending a readjustment of the formula following the work of Mr. Dunham with the coöperation of Dr. Levine, Dr. Norton, and others, it is not settled whether it will be considered desirable to extend this work still further using an improved medium. It is desired, however, to know reasonably accurately what may be expected of any modification of the medium before embarking upon another extensive program of investigation.

CHEMICAL METHODS

The mineral analysis of water, Mr. R. C. Bardwell, Referee

Further tests have been made in connection with the rapid method of mineral analysis of water for boiler purposes in accordance with the recommended procedure published in The Journal, August, 1925.

No criticism or further suggestion has been received. It is again recommended by the referee that the published procedure be adopted for standard practice in the examination of water for railway boiler purposes and small steam supplies.

Mr. Bardwell, the referee, is a member of the committee on Boiler Feed Water Studies under the Chairmanship of Mr. S. T. Powell. Sub-Committee No. 8, of this General Committee, under the Chairmanship of Mr. Harold Farmer, is giving consideration to the analysis of water for steam boiler purposes, with particular reference to the preparation and adoption of standards which may be classified as the referee methods. Study is being given the present methods in use for determining "dissolved oxygen" and free carbon dioxide as applied to boiler feed water investigation, but the committee is not yet prepared to report definite recommendations.

The determination of turbidity and coefficient of settling, Mr. John R. Baylis, Referee

Encouraging reports have been received from a number of laboratories using the Baylis turbidimeter. There are now between 60 and 75 laboratories in which the instrument is in use for testing the clarity of filtered water. A few of the users of the turbidimeter have been questioned as to its accuracy and convenience in making turbidity determinations to 0.1 part per million and seem to agree that it can be handled by any one. No suggestions have been made as to improvements.

A new floc-detector for use in testing the floc turbidity passing filter beds has been designed and will be tried out after the experimental filter plant at Chicago is put in operation. Work on the development of a convenient instrument for testing turbidities between 2 and 25 is under way.

Considerable time is being given to the physical and chemical characteristics of suspended matter occurring in surface waters.

The detection of phenols, Professor C. S. Boruff, Referee

Professor Boruff, of Monmouth College, and one of his research students, Mr. Kenneth Irey, have been giving the phenol detection problem considerable attention the last few months. The referee has corresponded with a number of plant operators and consulting chemists and has found a great difference of methods and results. All seem to be anxious for a standard method. A number of these men have offered valuable suggestions which are being incorporated into the attack on this problem. The referee at this time wishes to voice his appreciation of these suggestions. The chemists of the United States Public Health Service, under the direction of Dr. H. D. Gibbs, have carried out some splendid work on this problem and already have produced three valuable publications which are as follows: Chemical Reviews, *3*:291 (October, 1926), Journal of Biological Chemistry, *71*, 445 (January, 1927); *72*:469 (April, 1927). Most other publications deal mainly with the cause of the taste and odors and not with quantitative methods of determining the causative agent.

Tests were made to determine which of the phenolic wastes caused the characteristic taste and odor upon chlorination. It was found that 1 p.p.m. of phenol and a small fraction less than 1 p.p.m. of the

cresols and aniline caused taste and odor in tap water. Other phenolic wastes gave no taste and odor, or if they did, the compounds were not believed to be of the type that would be found in wastes. The literature tends to bear out the above conclusions. Organic matter, pH, and certain mineral constituents seem to affect the sensitivity of the individual to the taste and odor. More work is to be carried out along this line of attack.

Upon examination the halogen and the ferric chloride methods were discarded on account of lack of sensitivity. The much used Folin-Denis method was studied quite thoroughly. By this method, small amounts of phenolic wastes may be detected but the test is not specific for products causing taste and odor. Furthermore it is not specific for aromatic compounds, since any reducing agent will give a positive test and color with this reagent under the conditions employed in the method.

The Millon reagent method was also investigated and has been found to be specific for aromatic OH and NH_2 compounds. The investigators are now testing the sensitivity of the different Millon and modified Millon reagents as made up by different formulas. The chemistry of the test is also being studied. The taste producing compounds may be detected by methods now being used in solutions containing as little as 0.05 p.p.m. It may be that this direct test can be made still more sensitive. Under present methods, amounts can be detected which are not sufficient to cause taste and odors upon chlorination.

Distillation methods with sulphuric acid give very promising results. Although some trouble has been experienced in getting consistent results, this method shows great possibilities and is to be studied at further length.

The investigators, Boruff and Irey, hope to have considerable data together by early summer in order that a paper may be prepared and offered for publication. In this paper the different promising methods will be critically considered, special attention being paid the one most likely to fit the needs.

The determination of free chlorine, Dr. A. M. Buswell, Referee

The work on the subject of free chlorine has not been carried on actively during the present year. Last year Dr. Buswell and Professor Boruff worked on the preparation of a suitable ortho-tolidine reagent. This year Dr. Buswell has devoted his energy primarily

to the study of subjects which interested him more. These were matters concerned with determination of nitrogen values and the type of soap solution used in the determination of hardness. Some work on the determination of free chlorine has been carried out by Mr. Enslow of the Chlorine Institute, formerly a member of Committee No. 1, who has called attention to the desirability of having a highly acid solution of ortho-tolidine without allowing the reagent to form a precipitate, thus weakening the strength of the solution for all effective purposes.

Mr. Emory J. Theriault, of the United States Public Health Service, has also made a study of the determination of free chlorine by the ortho-tolidine method and has published his work in the Public Health Report of the United States Public Health Service under date of March 11, 1927. The report of Dr. Buswell's work on the nitrogen determination will be found under the names of Neave and Buswell in The Journal of the American Water Works Association, vol. 17, no. 3, pages 388-395, March, 1927. In this work he questions particularly the albuminoid nitrogen determination.

The determination of iodine in water, Mr. Dale L. Maffitt, Referee

Changes in Mr. Maffitt's work have taken him out of the laboratory for a considerable portion of his time. He has, however, in collaboration with his assistant, Mr. M. K. Tenney, had the opportunity to make some determinations of iodine according to methods which have been proposed, with the idea of eliminating those least favorable for the purpose. A study of the different methods used for the determination of iodine in waters shows that they may be classified into two groups. The first group involves the addition of potassium iodide, and the subsequent titration with sodium thio-sulphate of the iodine liberated, while the second class depends upon the color formed in an organic solvent, such as carbon bisulphide, carbon tetrachloride, and the like, by the iodine present in solution.

The first class of methods is not considered promising for the reason expressed in the following sentence taken from E. F. Eldridge's report in the American Journal of Public Health for September, 1924: "These methods were ruled out because of the effect of the constituents of certain waters on the iodine added caused a liberation of iodine, and also because of the instability of the extremely weak thiosulphate necessary." The colorimetric methods studied may be

divided in turn into two groups, depending upon the oxidation of the organic matter with potassium permanganate as used by Eldridge in the work referred to above and the other method in which the organic matter is oxidized by ignition as described by Dr. J. F. McClendon in the Journal of Biological Chemistry for June, 1924, page 189, and also by Von Fellenberg (Mitt. Geb. der Lebensmitteluntersuch. u. Hyg., 161, *14*, 1923).

In any of the methods thus far proposed it is necessary to evaporate quite large amounts of the water sample to a small volume after first making the sample alkaline. When the evaporation has reached the point where a moist saline mass remains, Eldridge recommends adding a considerable amount of 95 per cent alcohol and filtering off the residue. Potassium permanganate in excess is added to the filtrate which is kept alkaline with sodium carbonate and the solution is cooled to below ten degrees Centigrade. A small amount of carbon disulphide is added and concentrated sulphuric acid is allowed to drop into the solution, care being taken not to raise the temperature. The sulphuric acid thus liberates the iodine which is taken up by the carbon disulphide. After the potassium permanganate color has been removed by hydrogen peroxide the carbon disulphide colored with the iodine is separated from the water solution and compared to standards.

According to McClendon's method, when the evaporation has proceeded until about one liter remains, the solids are filtered out and the filtrate is evaporated to dryness, transferred to a nickel boat and ignited in a combustion tube to remove the organic matter without loss of iodine.

The ash is taken up with water, neutralized with acid and transferred to a separatory funnel. To the solution in the separatory funnel is added carbon tetrachloride, one drop of concentrated hydrochloric acid and one drop of arsenous acid. Then nitrosylsulfuric acid is added to liberate the iodine which is taken up by the tetrachloride, imparting to it the color which McClendon compares with a standard using a Bausch and Lomb microcolorimeter.

Under different conditions each of the above described methods have some advantages and some disadvantages. In the presence of large amounts of iodine and the absence of bromine the method of Eldridge probably would be preferable. But, if bromine is present when the sulphuric acid is added in the permanganate method, the

bromine is liberated imparting a brown color to the organic solvent, sometimes masking the color due to iodine. To overcome this difficulty potassium sulphocyanate is added to remove the bromine. However, unless care is used in the addition of the sulphocyanate, the iodine may be reduced to hydrogen iodide and lost, thereby making a place for possible error. Experience with the two methods leads the referee to share with W. Von Steffens (Z. angew. Chem. 39, 1098 (1926)) the opinion that the ignition method is more desirable.

The preparation of an ignition tube and the process of burning the residue in it probably takes a little more time and requires somewhat more elaborate technique than the permanganate method. However, it was found that a combustion tube could quite easily be made by heating a section of a Pyrex tube, 1 inch in diameter, in a blast lamp, drawing the tube out to about $\frac{1}{4}$ inch in diameter. The drawn-out portion is then bent at right angles where it commences to taper. A tube about 18 inches long and 1 inch in diameter with about five inches of the drawn-out portion $\frac{1}{4}$ inch in diameter beyond the bend, is a convenient-sized combustion tube.

Although Dr. McClendon and also F. E. Daniels (Journal of the American Water Works Association, vol. 16, page 227, August, 1926) and the others who have used this method all recommend passing oxygen through the combustion tube during ignition, satisfactory results were obtained by drawing air through the tube by means of a small filter pump, thus eliminating the necessity of a tank of oxygen. In a recent communication Dr. McClendon suggests that where extreme accuracy is not required, the combustion tube can be eliminated altogether and the ignition accomplished in a porcelain dish by very careful heating so as to oxidize the organic matter with as little heat as possible, thus reducing any loss of iodine to a minimum. Dr. F. E. Hale, of the Mt. Prospect Laboratory, Brooklyn, New York, and Dr. G. W. Goler, Health Officer of the city of Rochester, New York, as well as F. E. Daniels and others, with whom the referee has communicated, and who use the ignition method, all seem to use an ignition tube of some type, but if the tube could be eliminated considerable time could be saved in the determination. Further investigation along this line is contemplated.

From his work, as far as it has progressed, the referee would recommend the following procedure as a tentative standard method:

MODIFIED McCLENDON METHOD FOR THE DETERMINATION OF IODINE IN WATER

Reagents

a. Sodium hydroxide solution, approximately 0.1 N.

b. Arsenous acid solution, approximately 0.1 N.

c. Purified carbon tetrachloride. Color technical carbon tetrachloride with chlorine or bromine, allow it to stand a week in sunlight, wash out the chlorine or bromine with sodium hydroxide solution, then with water and separate by first syphoning off the water, then filter the remaining liquid through a layer of plaster of paris. Distill, rejecting the cloudy first portion of distillate.

d. Nitrosyl-sulphuric acid solution. In a side arm distilling flask heated by a water bath place a starch paste made by mixing 50 grams of starch and an equal amount of water. Allow nitric acid, specific gravity (1.35), to run in from a dropping funnel in the stopper onto the hot starch just fast enough to keep a steady stream of oxides of nitrogen coming over through a delivery tube connected to the side arm of the flask and dipping into 30 cc. of concentrated sulphuric acid. The product is a nearly saturated solution of nitrosyl-sulphuric acid in sulphuric acid. In a closed bottle it keeps indefinitely.

e. Standard potassium iodide solution. Dissolve 13.5 mgm. of potassium iodide in a liter of distilled water. (1 cc. = 0.01 mgm. I.)

Procedure

Make alkaline with sodium carbonate 50 liters of the sample water (100 liters if the iodine content is low). Evaporate in a large evaporating dish into which more of the sample may be syphoned from a large tank or carboy as it boils away. The crust of calcium salts or residue left in the tank or carboy is discarded. When the evaporation has proceeded until about one liter remains, filter out the solids, and evaporate further to 50 cc., filter into a nickel or platinum dish, washing the residue with a few cc. of hot water and evaporate to dryness over a water bath or in an oven set at 110°C. Pulverize the residue and transfer the dry powder to a nickel boat. Insert the boat into the center of the Pyrex combustion tube[2] which has a drawn out portion one quarter inch in diameter on one end bent down and passing through one hole of a two hole stopper into 30 cc. of 0.1 N sodium hydroxide solution in a pyrex test tube. Through the other hole in the stopper place a piece of right angled glass tubing which does not reach down to the liquid in the test tube, so that when suction from a small filter pump is applied to this tube the air being drawn through the combustion tube will bubble up through the sodium hydroxide solution. With the suction pulling air through the tube at the rate of 3 or 4 bubbles per second, heat the tube and boat carefully, avoiding fusion of the ash. The powder will turn black, then white, showing that the combustion is complete. If the alkaline solution becomes very discolored it must be evaporated and burned again, but the ash will not have to be treated again. Transfer the ash from the boat to a 100 cc. beaker and rinse out the tube with the alkaline solution, pouring rinsings into the beaker. Boil the solution, stirring the

[2] The combustion tube has been described above.

residue until it is dissolved or thoroughly leached out. Evaporate to about 20 cc. and filter. Neutralize the filtrate with phosphoric acid, using phenol red paper for the indicator, add a drop of arsenous acid and transfer to a 30 cc. separatory funnel. Add phosphoric acid to a yellow color with brom-phenol blue test paper, then add 1 cc. of purified carbon tetrachloride and a drop of nitrosyl-sulphuric acid, shake 100 times and allow to settle. Drain off the carbon tetrachloride into a small test tube, such as a small bacteriological fermentation tube. Repeat the extraction adding the second cubic centimeter of carbon tetrachloride to the first in the small tube and compare with standards. The standards are made by diluting 0.5, 1.0, 5.0, 10.0 and 15.0 cc. of the standard potassium iodide solution to 20 cc. and treating the same as the water sample. Each solution is placed in a small separatory funnel and a drop of 0.1 N arsenious acid added. Two extractions with carbon tetrachloride and nitrosyl-sulphuric acid are made and the carbon tetrachloride solutions are run into tubes similar to the one containing the iodine from the water sample. The standards made will represent 5, 10, 50, 100, 150 and 200 billionths of a milligram of iodine in the sample. Therefore divide the result by the number of liters evaporated and report as parts per billion of iodine.

The determination of bio-chemical oxygen demand, Dr. F. W. Mohlman, Referee

The biochemical oxygen demand determination is probably the most significant and useful of all analytical determinations in the analysis of sewage and polluted waters, but its use has not been as widespread as might be expected, since difficulties in technique and apparent discrepancies sometimes discourage the analyst. During the past ten years, research in various laboratories, notably the work of E. J. Theriault of the United States Public Health Service, has explained many of the difficulties encountered in earlier work, but much remains to be done in order to standardize the analytical procedure. Interpretation and use of the results is another problem that requires investigation, but this Committee's work is concerned primarily with the standardization of the analytical procedure with a view toward revision or improvement of the technique now recommended in the last (1926) edition of Standard Methods of Water Analysis.

The fundamental requirement is the use of diluting water that has a very low oxygen demand. E. J. Theriault (1), of the United States Public Health Service, first proved in a conclusive manner that the difficulty experienced by so many analysts in getting check results in several dilutions was due to the use of diluting water having an appreciable oxygen demand.

In the work in the laboratories of the Sanitary District of Chicago, it has been found that the greatest difficulty in the use of the B.O.D. test has been in preparing uniform, satisfactory diluting water. There are eleven control and field laboratories of the Sanitary District in which more than 100 oxygen demand determinations are being made daily, extending 250 miles down the Illinois River. There are nine varieties of tap water available in these laboratories, mostly deep well waters containing iron or manganese, nitrites and nitrates. It appeared impossible to obtain concordant results among all laboratories using such a variety of waters, consequently comparative tests were made. Distilled water was unsatisfactory, giving low results. In one case where high dilutions were used (1 to 200) the distilled water results were 35 per cent lower than those obtained with stored tap water.

In order to approach uniform conditions it was thought desirable to try distilled water containing an added quantity of salts. Comparative tests were made using distilled water to which 500 parts per million of sodium bicarbonate had been added. The bicarbonate acts as a buffer, furnishes the salt content required in high dilutions, and is a normal constituent of most natural waters. Results with this dilution water were near the average of all waters used, much above distilled water, but lower than Chicago tap water, a surface water containing a small amount of organic matter.

Since June, 1926, practically all of the Sanitary District laboratories have been using this type of diluting water with very satisfactory results.

Further investigations are necessary to determine whether some salt or combination of salts is more desirable, and whether 500 p.p.m. or some other concentration is best. A more complex synthetic dilution water has been used by Greenfield and Elder (2) containing the following salts:

Salt	*Parts per million*
Calcium chloride—$CaCl_2$	165
Magnesium sulphate—$MgSO_4 7H_2O$	285
Potassium chloride—KCl	10
Sodium bicarbonate—$NaHCO_3$	336

The use of this dilution water gave higher results than when distilled water was used. When the concentration was doubled slightly higher results were obtained.

Theriault has done some preliminary work with phosphate buffers. A recent paper by Cooper and Read (3) indicates that the use of potassium di-hydrogen phosphate, KH_2PO_4, accelerates the rate of demand by stimulating the growth of bacteria. Other phosphates did not show the same effect.

Gaunt and Abbott (4), as a result of some coöperative work at Shanghai, concluded that the use of chlorinated water, even after the residual chlorine has disappeared by prolonged storage, is undesirable for use as dilution water in the determination of biochemical oxygen demand due to some inhibitive effect, but their data are not very concordant and indicate that the waters used for dilution may not have been identical, except for addition of chlorine.

Variation of results when using different types of dilution water have been noted by English investigators, but apparently a standard dilution water was not prescribed for the Royal Commission 5-day test.

In view of the general indications that such a standard dilution water is desirable, it may be a proper function of this sub-committee to plan some coöperative work on this subject during the coming year. Comparisons might be made of the following dilution waters:

1. Stored tap water
2. Distilled water
3. Distilled water plus bicarbonates
4. Distilled water plus bicarbonate, sulphates and chlorides
5. Distilled water plus phosphates

Other variations of a standard dilution water will go a long way toward clearing up some of the difficulties that have been encountered in the determination of the biochemical oxygen demand.

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(2) Further Studies on the Biochemical Oxygen Demand Test. R. E. Greenfield, A. L. Elder, and R. E. McMurray. J. Ind. and Eng. Chem., 18, 1276–79 (December, 1926).

(3) Studies on the Dissolved Oxygen Absorption Test. E. A. Cooper and W. H. Read. J. Soc. Chem. Ind., 46, 154–6 (April 22, 1927).

(4) The Effect of Chlorine on the Absorption of Dissolved Oxygen by Polluted Waters. P. Gaunt and W. E. Abbott. J. Soc. Chem. Ind., 45, 323 (September, 1926).

MICROSCOPICAL METHODS

The microscopical examination of water, Mr. W. F. Langelier, Referee

A detailed report by the referee has been published in THE JOURNAL, April, 1928, page 408.

It is the desire of the referee to continue the investigation with a view of developing a standard plankton net and also a standard method of collection and enumeration of plankton organisms taken by this net, with a view to its possible adoption as an optional procedure to rank with the Sedgwick-Rafter method.

The field representative, Mr. Lewis I. Birdsall

In his capacity as field representative of Committee No. 1, Mr. Lewis I. Birdsall has been most helpful in suggesting persons who would be likely to be interested in assisting in the research work carried out by the committee. Mr. Birdsall has also informed us where certain types of research work were in progress and also where methods of current use were not giving the results desired. This type of information is exactly what is needed for the conduct of the work of Committee No. 1 in order that it may function in a manner most useful to the entire water works industry.

RECOMMENDATIONS

Your Committee No. 1 would respectfully recommend, with regard to the continuance of work along the line attempted by the Committee under instructions from the Standardization Council, that:

1. The work on the study of the composition of brilliant green bile be continued and that correlation work on the use of this medium as a secondary fermentation medium be studied further. If the work on the composition of the medium tends to indicate that there is need of such a study, the work on the use of the improved medium as a primary fermentation test be repeated.

2. Such new special media as may be developed from time to time shall be given preliminary study such as has been given the Salle medium during the current year. The tests should be more extensive if this seems advisable.

3. The study of non-confirming spore formers be further continued along the line suggested by the referees.

4. The eosine methylene blue agar and modifications thereof be studied to see if it is possible to obtain a more uniformly accurate differentiation between the colon and the aerogenes type organisms, and that the latter be studied in regard to their tendency to overgrow organisms of the colon type. If possible some method should be devised to restrain aerogenes organisms from interfering with the detection of the colon type of organisms, which are probably more significant from the standpoint of the water works operator.

5. The use of brilliant green lactose bile as a primary fermentation medium, when used in parallel with lactose broth fermentation tests or as a secondary fermentation medium following primary fermentation in lactose broth, be included in the standard procedures for the detection of the colon group of bacteria.

6. The referee on mineral analysis of water continue to act as liason agent with Mr. Farmer's Sub-Committee No. 8 of the general committee on Boiler Feed Water Studies under Mr. Powell, and that he inform the Chairman of the Committee promptly concerning any possibilities of undesirable duplication or cases in which close coöperation is especially desirable.

7. Additional work be undertaken on the determination of free chlorine, and especial attention be given to increasing the hydrogen ion concentration of the ortho-tolidine solution without at the same time causing a precipitate of the reagent used.

8. The work on the determination of turbidity and coefficient of settling be continued as indicated in the report of Mr. Baylis. Especial attention be given to the determination of turbidity values lying between 2 and 25 parts per million on the silica standards.

9. Work on the determination of iodine be continued and an effort be made to secure trial of the method as proposed by the referee.

10. The work on the determination of biochemical oxygen demand be continued and the suitability of such processes as the use of sodium bicarbonate for the preparation of standard diluting waters be studied in laboratories as widely separated as possible.

11. The net method of Hensen for the estimation of plankton be further studied and an attempt be made to develop a standard plankton net and a standard method of collection and enumeration of plankton organisms taken with that net, with a view to the possible adoption of an optional procedure to rank with the Sedgwick-Rafter method.

12. Intensive work on the determination of dissolved oxygen be

undertaken in coöperation with Sub-Committee No. 8 of the Boiler Feed Water Studies Committee and in the study attention shall be paid both to the determination as applied to sewages and natural waters and also to the highly heated waters of low oxygen content which are met with in boiler feed water practice.

13. The determination of free carbon dioxide be studied coöperatively with Sub-Committee No. 8 of the Boiler Feed Water Studies Committee.

14. One or more additional field representatives be selected from among the men who are in close contact with laboratory work in water plants throughout the country and who travel as representatives of industrial concerns or trade institutes. This recommendation is made because of the feeling that additional information from such sources is essential to the success of the Committee work.

15. Since the detection of phenols is very important in the treatment of water supplies at the present time and it is highly desirable that suitable accurate methods shall be generally used throughout the industry, the work on phenols should be continued and be prosecuted with the greatest energy.

16. Subject to the approval of the Standardization Council, Committee No. 1 be authorized to include in its membership such additional referees as may be necessary to handle problems which may arise during the year between the Convention in June, 1927 and that in the summer of 1928.

Committee No. 1 has followed the policy of allowing free publication of results obtained by the referees and their collaborators. It is hoped that in every case each worker may receive the recognition and the credit due him for the work he has conducted. While the Committee can accept no responsibility for statements and results presented other than those appearing in its periodical reports, and which have the endorsement of the Committee as a whole, the Committee recommends that all those connected with its studies allow the Journal of the American Water Works Association prior opportunity of publication. In the event that sufficient space is not available in the Journal, it is recommended that the publication of the articles based on topics under discussion in connection with the work of Committee No. 1 be offered for publication in places where they will be most readily available to men in the water works industry.

Committee No. 1 is always anxious to receive suggestions and criticisms from anyone interested in its field of work. Such communications will be carefully considered and if advisable forwarded to specialists in the field for advice and study.

Respectfully submitted,

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J. R. BAYLIS
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JACK J. HINMAN, JR., *Chairman.*

PROGRESS REPORTS OF THE BOILER-FEEDWATER STUDIES COMMITTEE

Report of the Advisory and Editing Committee[1]

By Sheppard T. Powell

At the first formal meeting of this Committee held last year at the Power Session of the Annual Convention of The American Society of Mechanical Engineers, reports were presented by the various technical committees as contribution to these studies. The communications were in the nature of progress reports and indicated the present status of the art of water purification and the listing of problems requiring further investigation. Practically all of these reports stressed the necessity of more accurate information on the treatment of feedwater, the need of fundamental data concerning the chemical phenomena of water treatment, and the desirability for intensive research as a solution for feedwater difficulties confronting the profession at the present time. During the past year these views have been confirmed by the many operating problems that have come to the Committee's attention from members of the profession who are seeking relief for specific failures which occur as a direct effect of the quality of feedwater used.

[1] The personnel of the Executive Committee of the Joint Research Committee on Boiler-Feedwater Studies is as follows:

Sheppard T. Powell, Chairman, Chemical Engineer, Baltimore, Md.

W. L. Abbott, Chief Operating Engineer, Commonwealth Edison Company, Chicago, Ill.

A. J. Authenreith, Vice-President, Middle West Utilities Company, Chicago, Ill.

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The present tendencies in steam-boiler design and the operation of steam generating equipment in stationary and railroad practice are having a marked influence upon the entire question of feedwater treatment. With these recent developments have come a series of influencing factors introducing new problems which may not be overcome without more advanced knowledge on the subject of feed treatment than is now available. Ten or fifteen years ago the majority of feedwater problems consisted largely of the removal of scale. The control of this problem is no longer an important one since equipment for the elimination of scale is now available. Deaeration of feedwater has done much to correct corrosion troubles. However, feedwater troubles have not been eliminated in all cases by the installation of deaerators. The corrosion of economizers and boilers, in the absence of oxygen, the production of hydrogen and oxygen by direct ionization of pure water, the embrittlement of boilers at relatively low pressure, and numerous other problems have been brought to the attention of the Committee during the past year. The conditions are indicative of the influence of present

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operating conditions of boilers, or possibly of the result of industrial contamination of surface-water supplies, to which little coöperative study has as yet been given.

Practically no information is available concerning the influence of volatile organic matter, especially organic acids, as a factor in the corrosion of steam boilers, yet many surface waters from which feedwaters are drawn are being constantly subjected to such pollution. It is difficult to obtain any reliable data on the effect of ammoniacal compounds in water and the effect of such compounds in the presence of high concentrations of alkaline salts. Numerous surface waters contain appreciable amounts of these substances as a result of domestic sewage or industrial-waste pollution of streams used as a source of supply, yet little attention has been directed to these conditions. There are no established methods available for determining the acidity or alkalinity of water at high temperature. It is fairly well known, however, that under high pressure and temperature these constituents are radically different from what they are when the samples of water are tested at room temperature.

Attention is directed to the recommendation of Technical Committee No. 5 which has been studying corrosion problems. A number of specific problems are listed which, in the opinion of the Committee, require study. The solution of any of these problems would have a marked effect in reducing corrosion of boilers, economizers, steam piping, and other appliances.

Priming and foaming are terms employed so frequently that it would appear that these are well-defined phenomena subject to control if ordinary precautions are employed. It was reported recently by one member of the Executive Committee that the failure to solve this trouble is resulting in a loss on one railroad of $100,000 annually. The particular road in question has already installed many complete water-purification systems which have effected great financial saving from the elimination of scale and corrosion, but priming and foaming of boilers is still far from accurate control. The various types of steam purifiers and similar equipment being offered at the present time indicate the magnitude of this problem. The economic importance of foaming boiler waters is recognized, but there is still little basic information concerning the physical and chemical properties of water responsible for these operating troubles.

The Committee reports on trade wastes of the American Water Works Association and the studies by state and federal bureaus furnish ample evidence of the gross pollution from industries. There

has been no comprehensive study of these conditions from the viewpoint of the use of water for boiler feed or cooling purposes. For some unaccountable reason, considerable apathy exists among power-station operators as to the glaring losses resulting from these conditions. Acute cases of accelerated corrosion due to acid contamination of streams has forced some industries to undertake corrective measures. The problems are so involved that isolated corrective treatment can have little or no effect in stemming these losses which are becoming increasingly more aggravated in many industrial areas. No progress in this field is possible until the profession is impressed with the seriousness of the problem. Although the control of conditions frequently requires legislative measures, coöperative investigations by interested industries are producing commendatory results. The Technical Committee studying this problem has been impressed by the lack of interest demonstrated by steam-station operators. This condition, we believe, is due largely to failure to recognize the importance of the problem and failure to grasp the significance of the ultimate effect of continued trade-waste pollution of surface streams and how these conditions will definitely influence the future operation of feedwater systems and surface condensers. The brief report of the Committee dealing with these problems should be given mature consideration by those companies situated in industrial areas.

Attention is directed to the important work of the Committee on Bibliography. From time to time this Committee has published short abstracts on interesting and new developments relating to feedwater treatment and allied subjects. The abstracts have been published in several journals, making these valuable contributions readily available to a large group of engineers who could not otherwise obtain these data without considerable effort.

The Finance Committee appointed early this year has given much thought to ways and means for raising funds to carry forward the desired research studies, and is confident of the fact that no great progress in this study can be made without a constructive paid research program. The committees requiring such assistance at this time are those to which have been assigned the following problems:

1. Corrosion
2. Embrittlement
3. Priming and foaming
4. Condensers, evaporators, and deaerators

It is the opinion of the Committee that since these problems are nation-wide in scope, the financing should not be borne by any individual group nor confined to any restricted area. The opinion of the Committee is unanimous that the financing of the proposed research studies is a sound investment which will effect an ample return in the form of reduced maintenance and higher efficiencies in the operation of equipment.

The Committee on the Standardization of Water Analysis has done constructive work, especially in cementing the contacts with organizations that have similar committees functioning. This has been responsible for eliminating duplication of effort, a condition that has caused much confusion in the past.

During the past year many committee meetings have been held and committeemen have traveled long distances at their own expense to attend these meetings. At the regional meeting of The American Society of Mechanical Engineers held at Kansas City in April and at the Annual Convention of the American Water Works Association in Chicago in June, 1927, a number of papers were presented as contributions from these studies. The interest in the Committee's efforts was demonstrated by the attendance at the Water Works meeting, when more than two hundred persons representing the power-plant and railroad fields were present at the session held under its auspices. At these meetings, the importance and magnitude of these problems were indicated by the active discussion that took place.

The most important work before the Executive Committee at this time is the inauguration of the proposed research program when the funds are available for these studies. It is proposed to carry the work forward in close coöperation with state and federal bureaus equipped for such work or at universities where engineering problems of a similar nature are in progress. By such procedure, there will be required a minimum expenditure for equipment and other necessary facilities. The Committee is impressed with the responsibility of this important work and earnestly solicits the coöperation and assistance of those interested in the program. The success of the undertaking will be measured largely by the financial assistance which the Committee receives.

The Executive Committee desires to express here its appreciation to the individuals and groups of committeemen who have made possible the success of this work to date.

DECONCENTRATORS AND CONTINUOUS BLOW-DOWN APPARATUS[1]

Progress Report of Sub-Committee No. 1 on Sedimentation With and Without Chemicals, Pressure and Gravity Filters and Deconcentrators, Continuous Blow Down Apparatus

By R. C. Bardwell

One of the most troublesome difficulties with which the operation of steam power plants has to contend, is the elimination of excessive moisture in the steam, "excessive" being a relative term applying to a small portion of one per cent at high-efficiency stations and varying to greater amounts which actually interfere with the immediate functioning of the equipment at others. Although the presence of this moisture is variously attributed to foaming or priming superinduced by (1) possible improper design of the boiler for the work being handled such as limited area of steaming surface or volume of steam space, (2) method of operating boiler, including sudden variation in load, height at which water level is carried, and irregular firing, and (3) composition of the water inside the boiler including concentration of alkali salts and suspended matter, and occasional presence of organic matter, it would appear that, under present-day operation, the limiting factor is considered to be largely

[1] The personnel of Sub-Committee No. 1 on Sedimentation With and Without Chemicals, Pressure and Gravity Filters and Deconcentrators, Continuous Blow-Down Apparatus, of the Joint Research Committee on Boiler-Feedwater Studies is as follows:

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controlled by the permissible concentration of foreign matter, and corrective steps have been mostly confined to schemes which will hold this concentration within workable limits.

There are three methods by which this concentration may be controlled:

1. Use of evaporators which may remove practically all of the solids from the feedwater, or partial reduction which may be secured by treatment of the incrusting sulphate with barium carbonate;

2. Removal of a portion of the suspended solids from the boiler water with the return of the water to the boiler without an appreciable loss of heat;

3. Suitable regulation of blow-down economically to control the permissible alkali salt concentration with utilization of the heat from the blow-down water to preheat the feedwater, where consistent.

The treatment of the feedwater is outside the scope of studies by this Committee, and this report will deal briefly with present development and trend of various means used to maintain the concentration of suspended matter and dissolved solids within workable limits.

Where water is used in steam boilers with a limited sedimentation period for the removal of suspended matter or no pretreatment for the elimination of the dissolved scaling matter before delivery of the feedwater to the boilers, the trouble caused by the subsequent accumulation of suspended matter in the boiler is only a question of time. Two schemes are in extensive use which have alleviated this trouble to some degree, one consisting of a small pressure filter through which a portion of the water from the boiler is passed continuously while the boilers are in operation with return of the clarified water to the boiler, and the other involving the sedimentation and settling of small portion continuous blow-down with return of recovered condensate to boiler and wasting of sludge and highly impregnated concentrate.

DECONCENTRATOR SYSTEM

The first system is termed a "deconcentrator" and was designed to prevent accumulations of suspended solids in the boiler. It is peculiarly adapted where internal treatment is practiced. The coarser suspended solids, which are coagulated silt present in the make-up water or the inert scaling matter which has been thrown

out of solution in the boiler under the influence of heat or internal treatment, are strained out by a non-siliceous filter medium.

The filter apparatus is under boiler pressure, but a small pump is necessary to overcome the friction of the piping system and filter medium in order that the clarified water may be returned to the boiler. Means for back washing are provided similar to other pressure-filter equipment, and a manually operated paddle or rake is supplied in order that the filter medium may be agitated in case it becomes clogged.

Sodium salts and other soluble matters are not removed by the deconcentrator but continue to accumulate in the boiler. However, careful experiments and practical results have demonstrated that the critical concentration with these salts is materially increased by removal of the suspended matter, and heavy blowing or water changes are postponed accordingly with the incident saving involved.

The advantages of the deconcentrator system are as follows:

a. Small space required and relatively low initial cost of installation and operation;

b. Partial saving in heat of blow-down water due to return of clarified boiler water while still under pressure;

c. Reduction in blow-downs due to higher allowable concentration of alkali salts; and

d. Adaptability for improving internal-treatment conditions by providing means for removal of the sediment and suspended matter incident to this method.

The disadvantages of the deconcentrator system are:

a. Necessity of frequent back washing when the boiler water contains high suspended matter;

b. Relatively high rates of filtration necessary under some conditions to handle the volume through the small effective filter area; and

c. Increasing operating difficulties in the maintenance of a series of filters and pumps when installed on a number of boilers.

STABILIZER SYSTEM

The second system is termed a "stabilizer" and is actually a continuous blow-down apparatus with provision made for recovery of condensate and prevention of appreciable heat losses. This is an improvement over the continuous blow-down devices ordinarily in use and has apparently met with considerable favor in many foreign power-plant installations.

The stabilizer consists of two parts. The upper chamber, into which the boiler water is led, acts as a flash tank, separating the steam liberated from the boiler water by the drop in pressure. This steam is then reclaimed as pure condensate in the hot well or feedwater tank. The lower part is a closed counterflow heat exchanger, the heat of the sludge water being transmitted through the metal pipes to the incoming feedwater. The sludge-water discharge is attached near the bottom of the lower chamber and carried up to a height sufficient to hold the chamber full of this waste water at all times, before it is drained to the sewer. The sludge is removed through a valve at the cone bottom of lower chamber.

The small amount of water wasted should be much more than offset by the advantage gained in reducing the alkali salt concentration as well as removing the mud and silt.

This type of equipment is also particularly well adapted for use with internal treatment as it provides an automatic means for removal of the precipitated sediment and also a control for alkali-salt concentration which is coincident with this method of treatment.

The advantages of the stabilizer system are:

a. Small space required and relatively low initial cost of installation and operation;

b. Partial saving in heat from blow-down water and the return of the pure blow-down condensate;

c. Smoothness in boiler operation due to maintaining more constant density of the water in the boiler; and

d. Adaptability for improving internal-treatment conditions by providing means for sludge removal and control of alkali-salt concentration.

The disadvantages of the stabilizer system are:

a. Necessity of check to prevent waste from the continuous blowdown;

b. Maintenance and cleaning of blow-off water compartment; and

c. Maintenance of cleaning of feedwater tubes of the closed heat interchanger.

CONTINUOUS BLOW-DOWN

As the critcal concentration is directly affected by the load distribution and boiler design as well as water quality conditions, it is necessary and advisable to determine this point for the individual plant. Then, by ascertaining the water capacity of the boiler and

the amount of impurities delivered with the feedwater together with the amount of water evaporated, a definite schedule can be calculated and put into effect for sufficient blowing down to maintain the boiler concentration within workable limits.

Precaution should be taken in securing a sample from the boiler which will be representative of the average concentration, as experience has shown that there is a marked difference in the density of water in various parts of the boiler. It might be well to secure samples from both the gage glass and blow-off connection for comparison.

Experience of a number of operators has shown that there is a marked difference in the concentration of solids occurring in different steam drums in the same boiler. Circulating tubes do not appear to correct this condition completely. It is desirable to take samples from each drum, and where wide variation in the concentration of solids is noted, special study should be given to correct the difficulty.

Although the concentration effects are largely governed by the total dissolved solids, this determination would not be practical in most cases for routine control so that some simple relative measurement is made from which the approximate total solid content is known by predetermined ratio. The chloride titration with standard silver-nitrate solution, potassium-chromate indicator, is frequently used. The amount of sulphates determined by photometric measurement after precipitation with barium chloride is sometimes used, and apparatus is available on the market for this application. The measurement of the density with a delicately calibrated hydrometer can also be used advantageously as a suitable index under fixed conditions.

The total-alkalinity determination is a simple and practical measure for determining the point at which boilers should be blown down, but it is not practical excepting in cases where alkalinity builds up in proportion to the total solid content of the water. The tests may be used to advantage where feedwater is treated by zeolite softeners.

After knowing the working quantity of water held in the boiler, the critical concentration point, and the rate of concentration increase, the amount necessary to be blown down to prevent trouble can be determined in accordance with the following general formula:

$$X = \frac{B \times C}{A}$$

where X is the number of gallons to be blown out in 24 hours; A, allowable concentration in boiler, grains per gallon; B, total solids in make-up water, grains per gallon; C, quantity of make-up water, gallons per 24 hours.

Where operation of the plant is complicated by condenser leakage, the pollution caused by salts in the circulating water should also be taken into account, together with the total solids in the make-up water.

By consideration of the boiler dimensions, the required lowering of the depth of the water surface in the gage glass may be determined and distributed hourly or per shift as desired. However, the boiler concentration should be checked occasionally to insure the desired benefits are being secured.

Numerous schemes for blowing down boilers have been devised in order to limit the concentration with as little loss of heat as possible and improve the smoothness of boiler-plant operation. In the development of the continuous blow-down, consideration has been given to the advantage gained by utilization of the heat from the blow-down water as well as the constant removal of the objectionable solids present in the water. Many of these devices are available on the market, some relying on manual control for constant delivery, and others attempting automatically to control the amount as required.

One of the interesting devices available consists of a continuous blow-down which is controlled automatically by the amount of water removed from the steam in the steam purifier. The separated moisture from the steam purifier is conveyed to the exterior of the boiler where it is discharged by a suitable steam trap of the piston-actuated type.

The discharge valve of this trap is opened by a steam piston operated by steam pressure admitted by a float-operated pilot valve when the trap chamber becomes filled. Since the filling of the trap chamber amounts substantially to a measure of the trapped moisture, the trap discharges correspond to the amount of moisture removed from the steam in the purifier. Thus, the number of trap discharges per unit of time will increase or decrease with the quantity and quality of the steam generated. The pilot valve of the trap may be used to open a separate piston-operated blow-down valve in unison with the trap discharges. A needle or adjustment valve also in the blow-down connection can be set to proportion this automatic blow-down to the discharge capacity of the purifier trap.

With this adjustment the automatic blow-down is controlled by the moisture content of the steam generated in the boiler. The workable concentration increases with light loads and decreases with the peaks. The compensating effect of this equipment provides for the necessary correction of the concentration with changes in load.

Another type of blow-off control in use consists of an open steel-tank weir box with an adjustable opening in the bottom. A continuous stream of the concentrated boiler water is discharged at a fairly constant rate through a heat exchanger to this blow-off control box and thence to the sewer. The constant head of water in the box over the weir opening is maintained by a float valve on the inlet side, which discharges water from the coil of the heat exchanger.

One of the difficulties to be anticipated in a continuous blow-down system is the corrosion and wear of valves and controlling appliances. With water free from suspended matter the depreciation of equipment in this respect should be relatively slight. Where suspended solids are present, the wear may be excessive. The most important advantage to be gained from this system is the control of soluble solids and finely divided suspended matter which are thrown out of solution in the boiler. Under these conditions the system is particularly adapted to boilers in which the make-up water has been treated externally and in which the majority of the solids concentrating in the boiler are soluble alkali salts.

The economic advantages to be gained by the system will depend largely upon the heat balance of the station. In the case of systems where there is a deficiency of exhaust steam, the heat extracted from the blow-down water may be used advantageously in raising the temperature of the feedwater. Continuous blowing down of boilers should not replace the regular blow-down valves, since even with these appliances in use, regular blowing down may be desirable or necessary.

At the convention of the Traveling Engineers Association, held in Chicago in September, 1927, careful consideration was given to the report of a special committee on the "Effect of Water Treatment on Locomotive Operation," which included the results of a study on the control of foaming tendency by the proper application and operation of blow-down appliances.

By government regulation it is necessary to drain the boiler and remove all washout plugs at least once every thirty days. However, in many cases under actual operation, especially in bad-water terri-

tory, it has been customary to wash or change water in locomotive boilers every few days, and in some cases after each trip, due to the foaming tendency cause by concentration of impurities.

In this report it is shown that suspended matter can be advantageously removed by the proper application of blow-off arrangements, eliminating the necessity for frequent draining and washing the boilers. By checking the critical dissolved-solid concentration for the respective districts, the necessary amount of blowing can be calculated from information on the amount and quality of water used, which will permit more satisfactory locomotive operation and avoid delays in turning these expensive power units at the terminals. Regular blowing at terminals is recommended, and in some cases small continuous blow-downs, made with a standard blow-off cock fitted with a bushing with hole $\frac{1}{4}$ in. diameter which will discharge about 600 gallons of water per hour, have proved particularly adaptable.

Descriptive drawings showing details of recommended applications and arrangements, together with typical instructions for road operation, are included in this report, which is of considerable importance in promoting improvement in locomotive operation.

RECOMMENDATIONS

There appears to be a considerable field for effecting economy in power-plant and locomotive operation through the improvement and standardization of suitable means for controlling boiler-water concentration. The importance of this subject appears to warrant special study and close review of existing devices and practices which are in service in this country, as well as foreign developments in this field, and is closely connected with the study on foaming and priming which is being made by Sub-Committee No. 3.

STANDARD METHODS OF WATER ANALYSIS

Progress Report of Sub-Committee No. 8 on Standardization of Water Analysis[1]

By Harold Farmer

The function of Sub-Committee No. 8 is to prepare standard methods of water analysis applicable to stationary and railroad practice.

Since this Committee is fostered by the Boiler-Feedwater Research Committee the writer has interpreted the function of this Committee to be the establishment of satisfactory methods for determining any constituent or property of water used as boiler feedwater for the generation of steam in connection with stationary and railroad practice.

Most of the methods of analysis of water for these purposes are covered by the standard methods of analysis published by the Ameri-

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can Public Health Association and are not in urgent need of revision. It has therefore been suggested by the Advisory Committee of the joint societies that attention should be first concentrated on those properties of water which influence corrosion of ferrous and non-ferrous metal, i.e., dissolved oxygen, CO_2, hydrogen-ion concentration, and alkalinity.

During the last year the personnel of the committee has been increased from six to twelve members. Activities have been confined to dissolved oxygen and CO_2.

Various methods have been collected and sent to the members for criticisms, and requests for additional data, and experience with other methods, have been solicited.

Unfortunately the chairman has not received very much discussion on the subject and very little in the form of suggestions has been forthcoming; therefore no active research has been possible.

Reviewing data presented by the members of this Committee it is very evident that for pure or distilled water the original Winkler method for dissolved oxygen is in favor. In fact, most of the members feel that this method is entirely satisfactory except that its ability to measure values of oxygen less than 0.05 cc. per liter is questionable.

A number of members draw attention to a very important fact, that the success of oxygen determinations is primarily dependent on the sampling of the water and that closer attention to the procedure of sampling is more needed than any modification of the actual determination.

Members have called attention to the necessity of using a good grade of soluble starch in this determination and that erratic results may be expected from the use of some of the common starches.

A method of collecting the sample under a film of oil to prevent contamination from air has been suggested by a member who follows this procedure in daily routine tests. Two members only have commented on this procedure and both indicate that their experience with this method and similar methods are more apt to contaminate the water, owing to the solubility of air in oil.

A radical departure from the method of determining dissolved oxygen was suggested by a member: that of employing an oxygen or hydrogen electrode as a means of ascertaining the amount of oxygen present in the water. This suggestion had not been applied and was purely theoretical. Only one member of this committee

commented on this method, pointing out that for laboratory purposes it promised great precision, but that in general use the electrode would be readily poisoned by impure water, and that if the samples were to be collected and tested by this method in the laboratory the possibility of their further contamination due to handling between the laboratory and the point of collection would more than offset the possible superiorities of the electrode measurement.

The writer has just completed an investigation in a large central-station plant during which more than 150 oxygen tests were made in 48 hours by the Winkler method, the sampling and testing being conducted according to *specific detailed instructions.*

The results of these tests were very gratifying as the different conditions under which the plant was operated were such that the periods when oxygen was present could be predicted. During this investigation operators were able to report values of oxygen as low as 0.025 cc. per liter, apparent lower values as a "trace," and values of "nil." This appears to indicate an accuracy for "distilled waters" which is not usually credited to the Winkler method. While not intimating that this degree of refinement can always be obtained, it is only fair to state that a great many of these results were supported by check tests. The writer, however, feels that the sentiments expressed by other members of the committee regarding strict attention to the procedure in sampling, play a very important part in the obtaining of reliable data.

From the comments of the Committee members and review of current literature and reports, the writer summarizes what he believes to be a review of the work attempted by this Committee and with the approval of the members of this Committee the following is submitted to the Advisory Committee as a progress report for 1927.

1. For pure or distilled water, and for values of oxygen as low as 0.05 cc. per liter, the original Winkler method should be presented as a tentative standard. A survey has indicated that no extensive investigation of this subject has been made since the one by E. J. Theriault reported in 1925. The subject has been very thoroughly investigated by him and reported in Public Health Bulletin No. 151. Until some further research is attempted this method should be given general use wherever possible. It is the sentiment of the Committee, in recommending the continuance of this method, that certain details of procedure be emphasized, such as the necessity of the use of a high grade of "soluble starch," and that too much im-

portance cannot be attached to the "collecting of the samples." It is proposed to write up in detail, instructions for the collecting of the samples along with the procedure of making the determination.

2. For waters containing "nitrates" and "iron salts" the Committee has been unable to locate any test that has been reported to have any advantage over the Rideal-Stewart modification as appearing in the standard methods of analysis of the A. P. H. A. and the modification and precautions given in Public Health Bulletin No. 151.

3. Various tests for the determination of CO_2 have been suggested. Most of these tests consist of absorbing the CO_2 with barium hydroxide or similar reagent and titrating the solution with sodium carbonate, using phenolphthalein as an indicator.

There appears to be no real advantage from these methods as they are all open to some of the supposed disadvantages of the present A. P. H. A. method—that phenolphthalein is not always a suitable indicator for this determination.

Other laboratories and members of this Committee have indicated that they have been unable to find any satisfactory method for this determination.

CONCLUSIONS AND RECOMMENDATIONS

From the exchange of opinions between members of this Committee and various laboratories, all indications are that for pure and distilled waters the original Winkler method is most satisfactory and that for waters containing nitrites and iron salts the modified Rideal-Stewart method seems to be in favor. The accuracy of both these methods for dissolved oxygen has been questioned and is a subject for further investigation. However, until some further work is done, it is suggested that every care be employed in collecting the sample. Precautions to be observed in collecting the samples will be presented when they have been approved by this committee.

All indications are that the present test for CO_2 is unsatisfactory, although the present A. P. H. A. test, in the absence of a better test, is believed by many to be the most desirable to use, and it meets some requirements.

It is recommended that the tests mentioned above for oxygen be presented as tentative standards for the present, and, as this Committee cannot undertake any extensive research work to establish the application of the tests for waters of varying natures, that a

fellowship be established in one of the universities or colleges to investigate thoroughly methods of determining dissolved oxygen.

In the absence of any suitable test for CO_2, no recommendations can be offered other than that this determination also be investigated thoroughly along with the oxygen determination.

The Committee feels that the above subjects are of such importance that they should be turned over to some agency for thorough investigation and that the magnitude of the work is such that it could not be attempted by members of this Committee who have their regular duties to perform and therefore such investigation would be subject to considerable interruption and delay.

GROUND WATER—DISCUSSION OF CHAPTER 4, MANUAL[1]

By W. G. Kirchoffer[2]

The subject of ground water is treated in the Manual of Water Works Practice in Chapter IV. The discussion of it covers only 10 pages and treats of the subject in a very general way. The average number of pages per subject is 24, so this subject has less than half the space it is entitled to.

This was due to the limited amount of time that the committee had in preparing the text and from the fact that this effort at text writing was no doubt the first for some of the contributors. In a first effort at book writing it is somewhat difficult to know just what should be included and what details are important and which are not. The chapter deals in a general way with the occurrence of ground water, how and where it may be found, but little on the works for its collection, treatment and quality. The subject of removal of hardness, iron and manganese should properly come under this title.

The origin of all ground water is the rain falling upon porous sandy soil or the upturned edges of rock strata. Almost all sedimentary deposits such as sand and gravel formations, sedimentary rock as limestones, shales and some sandstones, contain minerals such as calcium, magnesium, iron and manganese in a soluble form. The pure rain water falling upon and seeping down into these formations readily dissolves out the soluble material and carries it along with the water. In this manner water becomes hard and often has tastes and odors that are unpleasant for domestic use. The mineral content of waters is ever on the increase, the more rapidly we remove the water from the ground and over prolonged periods the greater will be the mineral content as a usual thing. This fact is especially true in the case of iron and manganese.

As an illustration, the city of Wausau has a ground water supply and has been bothered with these elements for many years. In 1905 the city sank some new wells to a depth of 134 feet, much deeper than

[1] Presented before the Wisconsin Section meeting, October 13, 1927.

[2] Sanitary and Hydraulic Engineer, Madison, Wis.

had ever been tried before. The water from these wells had only 0.05 p.p.m. of iron at the time they were drilled. In 1917, twelve years later when I undertook an investigation of the supply, I found anywhere from 0.20 to 15.0 p.p.m., averaging 2.50 p.p.m. In twelve years the iron content of the water had increased fifty times its original amount. Other cities in the state are having similar experiences.

It is not surprising that we should find iron in our ground water when we stop to think that iron is mined in large quantities both northeast and northwest of us and, at several places within the state, it is found to a less extent. Iron comes from the ground and not from iron pipes.

The southern half of the state south of a somewhat crescent shaped line passing through Green Bay, Stevens Point, and Hudson is underlaid with thick layers of limestone. In this area we find most of our hard waters, although there are some soft waters south of this line and some hard ones north of it.

Manganese is a most difficult element to remove and when present in quite small amounts is a real menace to a water supply.

The Manual in its treatment of this subject is very weak and needs much revising and bringing down to date. Manganese often occurs in combination with other substances such as organic matter and in this combination it is most difficult to remove.

Some authorities claim that iron and manganese in amounts in excess of 0.50 p.p.m. will cause trouble, but I have found that the limit is nearer 0.30 p.p.m. It depends on how the iron or manganese is held in solution as whether it will give trouble or not.

Ground water as a source of supply is important when considered for villages and small cities, but becomes unimportant when considered for large centers of population. Madison is one of the few comparatively large cities supplied with ground water in this country. Even of this size there are comparatively few cities that have ground water supplies. Memphis, Tenn. is about, if not the largest, city in the United States supplied with ground water. Formerly cities like St. Paul, Minneapolis, Indianapolis and Brooklyn, were supplied from this source, but have long since abandoned it for surface supplies.

The principal difficulties and disadvantages with ground water supplies on a large scale are to secure an adequate supply within a reasonable area and at a reasonable expense, to separate the water from sand when pumping at high rates; the universally hard water obtained from the ground due to the lime and mangnesium and to

the frequent presence of iron and manganese in objectionable quantities.

The improved methods of filtration and disinfection have been an important factor in the abandonment of ground water supplies for surface supplies. Recently two cities in this state were compelled to treat their ground water supplies due to the presence of iron and manganese. I am quite sure that had a suitable surface water been available, the ground water supplies would have been abandoned. There are other cities in this state similarly situated. They will have to treat their supplies in the near future due to the presence of iron and manganese, but they have available a surface water of suitable quality and quantity.

From the standpoint of the small city and village, ground water will remain an important source of supply for all time and therefore should receive its proper consideration. One of the most difficult things to do and one that is seldom done efficiently is to determine in advance the proper method of development and the probable amount of water obtainable from a given development.

The study of the hydraulics and mathematics of the flow of ground water is a most interesting topic to any one engaged in research work of that nature.

Many writers have attempted to derive a formula for the flow of water through porous material such as sand and gravel. This is comparatively easy when the flow takes place all in one direction as it does in a slow or mechanical filter, but when it comes to solving the problem where the flow comes from all directions, as it is likely to do in a well, the problem is very complex.

Some twenty odd years ago I made a study of all of the literature on this subject available in the libraries here, including some German and French writers. Unfortunately most of those who attempted this solution were scientific rather than practical men. Although most of the investigators used different symbols to represent the same function of the problem and approached the problem from slightly different angles, the resulting laws or formulas could all be reduced to the same thing.

Nearly all investigators assumed that the flow of water was radial from all directions to the well and in horizontal planes. Although this law has been derived repeatedly in text books, I never have been able to make any practical application of it and I never found any one else who had. I have, therefore, been on the lookout for some

formula or law that would truly express the relationship between yield of the well in gallons per unit of time the draw down or lowering and the characteristic of the formation or the transmission constant of the formation as defined by some writers and designated as K.

In some of my work, where the formations lay close to the surface, I was able to secure a draw down curve from observations on several wells while pumping one well. From a study of these data I was able to derive a law of flow or formula expressing the relationship between draw down, diameter of well and quantity pumped. The law may be stated as follows:

Draw down is equal to the quantity pumped per minute in gallons raised to the "a" power, divided by a constant "c," times the radius of the well to the "b" power in which "a," "b" and "c" are constants determined from the test on the supply in question. If we represent draw down by "L" and radius of the well by "R" and gallons per minute by "Q" the law expressed in logarithms is, $\log L = a \log Q - b - c \log R$.

This formula is of the same form as that for a vortex whorl or the surface curve of water discharging through an orifice in the bottom of a tank or receptacle. Stated in another way, it would appear that the assumption that water flowed radially to a well in horizontal lines did not fit the actual conditions as well as does the assumption that water flows into the well more in the manner of water falling through an orifice. This formula was first worked out and used on the design of the well at Waupaca and for that well the equation is $\text{Log } L = 0.93, \log Q - 1.024 - 0.6\ R$.

The procedure for practical application was something like this. A good water bearing formation having been located by the use of test wells and analysis of the sand samples, collected from them, a test well for pumping purposes was sunk at the site for the completed well.

I will not stop here to explain my method of locating such a supply. The test well for pumping purposes could be an open well or one using any form of well screen. Observation wells consisting of $1\frac{1}{4}$-inch well screens were sunk at intervals of 5, 10, 15, 25, 50 and 100 feet from the site in four radial lines and into the waterbearing formation to be used. The lowering of the water in all of these wells was observed at intervals of fifteen to thirty minutes during pumping. The discharge was measured by weir or meter. Pumping was continued until the lowering of the water in the observation wells had

practically ceased. The last set of observations gave the approximately true curve for the number of gallons pumped. It is not necessary to pump as many gallons per minute as is estimated to be necessary on the final development, but the larger it is the less likely there will be errors in the final result.

One test will give the data for pumping that quantity of water from different diameters of wells and for the corresponding draw down. In other words it establishes the relationship between draw down and diameter of well. To get the relationship of quantity to these other two factors it is necessary to make two or more tests at different rates of pumping.

From these data the constants for this formation may be derived and substituted in the formula mentioned heretofore. By this formula the yield may be predicted for any given draw down and diameter of well or vice versa.

In the case of the Waupaca well it was estimated that 900 gallons per minute could be obtained with a draw down of 9 feet from a 30-foot diameter well. An actual test found it to be 8.9 feet. Another test on the completed well when 738 gallons per minute were being delivered, checked with the computed draw down within $\frac{3}{8}$ of an inch. Similar tests made at Black River Falls, Antigo, Stevens Point, Port Edwards and Nekoosa, further demonstrated the adaptability of the formula to actual conditions. It was found that these formulas were equally useful in estimating the probable yield of a proposed well of different diameters for any given draw down. These draw down curves can and have been used to predict the yield for a gang of wells or from a gallery or trench.

I have found that the interference of one well upon another is measured by the draw down curve. By a summation of the draw down at the distances from the main well, corresponding to the spacing of the wells, the total draw down is given when each well of a gang is pumped the same amount as was pumped from the well in the test.

AN IMPROVED METHOD FOR PHENOL DETERMINATIONS

By John R. Baylis[1]

Methods most commonly used for estimating small quantities of phenol in water are not specific for phenols as a class and the characteristic phenol color is produced by certain other compounds present. Distilling the water usually removes part of the interfering compounds, but most surface waters will have at least some of the interfering compounds carried over with the distillate. As a result, it is difficult to get blank determinations on some waters where it is known that phenols could not be present in the quantities indicated.

Various amounts of phenol have been given as the minimum that will cause a taste after the addition of chlorine to the water, the lowest with one or two exceptions being about 2 parts per billion. It is likely that this figure is too low, but the amount probably is considerably less than 10 parts. For the Lake Michigan water it is believed that the point where chlorophenol tastes become noticeable is about 5 parts per billion. Very disagreeable tastes were noted when 10 parts were present, although some of this taste was probably due to compounds other than phenols. The addition of 10 parts per billion of pure phenol to the filtered lake water with enough chlorine to produce 0.10 to 0.20 part per million of residual chlorine produced only slight chlorophenol tastes. There is no assurance, however, that this was the optimum amount of chlorine to bring out the most pronounced chlorophenol taste.

A variety of opinions exist as to the cause of certain tastes occurring in many of our water supplies. There is a tendency to place all blame on phenols, if it is possible for such compounds to be present. Attempts to eliminate or reduce the taste have brought out several methods of treating the water. Superchlorination followed by dechlorination has been reported to give very good results at some places, whereas at other points this treatment does not seem to improve conditions materially. The addition of ammonia shortly

[1] Department of Public Works, Chicago, Ill.

before the chlorine is added has been helpful in keeping down the taste in a few cities. Treating the water with lime to the point where chlorine is eliminated entirely has also produced good results. Not enough work of this kind has been done as yet to state the limitations of these treatments. Certainly none of them is suitable for all conditions. Nothing would be of greater aid at the present time in helping to bring order out of what is almost chaos than methods for determining the compounds responsible for the tastes.

ACCURATE PHENOL TEST HAS BEEN DEVELOPED

An accurate quantitative method for determining the phenol in water supplies will aid materially in a better understanding of the causes and prevention of some of the disagreeable tastes frequently occurring in public water supplies. With the accumulating evidence from various sections of the country indicating that about 5 parts per billion of phenol, or even less when certain other compounds are present, are the limit beyond which it is not safe to go to keep from producing chlorophenol tastes, the need for a method that will detect phenols well below this point becomes apparent.

The attempt to work out a procedure for estimating less than about 10 parts per billion of phenol by use of the Folin and Denis (phosphotungstic-phosphomolybdic acid) or the Fox and Guage (diazotized sulphanilic acid) reagents on the Lake Michigan water did not offer much encouragement, due to the fact that certain interfering compounds could not be eliminated. When the test showed 3 to 4 parts per billion of phenol or less there was no way of telling whether any or a large percentage of the color produced was actualy due to phenols. If the taste producing point was 20 to 30 parts per billion of phenol, then the presence of other compounds which will produce a color equal to 3 or 4 parts would not be so serious, but with 4 to 5 parts being near the point of taste the need for a more accurate method of determining phenols is evident.

The excellent work by Gibbs[2] has added much to our knowledge

[2] Gibbs, H. D. 1926 and 1927. Phenol tests. I. A classification of the tests and a review of the literature, Chemical Reviews, Vol. 3, No. 3, 291–319, October, 1926. II. Nitrous acid tests, Journal of Biological Chemistry, Vol. 71, No. 2, 445–59, January, 1927. III. The indophenol test, Journal of Biological Chemistry, Vol. 72, No. 2, 649–64, April, 1927. IV. A study of the velocity of indophenol formation, Journal of Physical Chemistry, Vol. 31, No. 7, 1053–81, July, 1927.

of phenol determinations. He describes a method for detecting phenols by the production of indophenols with quinonechloroimides. 2,6-dibromoquinonechloroimide and 2,6-dichloroquinonechloroimide were found to be the best reagents. The test was reported by Gibbs to be sensitive to at least 50 parts per billion, which, if true, would not be sensitive enough for detecting phenols in water supplies. The procedure as worked out for use of these reagents at the Chicago Experimental Filtration Plant shows the method to be more sensitive than was reported by Gibbs, 5 parts per billion being about the minimum amount that can be detected without concentrating the phenols. Gibbs gave much information as to the characteristics of these compounds, but did not give a quantitative procedure. The purpose of this paper is to offer such a procedure.

METHOD FOR MAKING QUANTITATIVE PHENOL DETERMINATIONS WITH 2,6-DIBROMOQUINONECHLOROIMIDE

Gibbs[3] has shown that the pH of the solution is an important factor in the rate of indophenol formation. The most desirable pH appears to be 9.8, and it should not vary from this figure more than 0.2 either way. That is, the pH should not be less than 9.6 and not more than 10.0. The pH of the samples and the standards for any one test should not vary more than 0.1 pH. This means that the solution must be highly buffered to obtain such uniformity. When the sample contains considerable CO_2 that can be driven off with the distillate the pH of the first portion of the solution collected may vary slightly from that of the others, if equal quantities of the buffer solution are added. This may be corrected by adding more buffer to the first portion of the distillate. Where there are a number of samples from the same source the excess of buffer solution needed can be determined only occasionally and this will not make the phenol determination such a burdensome test. The addition of caustic lime to the solution before evaporation will prevent most of the acid compounds going over and does not seem to interfere with the test.

Reagents

1. *Alkaline sodium borate buffer solution.* Dissolve 15 grams of anhydrous sodium tetraborate powder in 900 cc. of distilled water. Stir vigorously while

[3] Gibbs, H. D. III. The indophenol test, Journal of Biological Chemistry, Vol. 72, No. 2, 649–64, April, 1927.

the powder is being added to the water to prevent lumping. Add 60 cc. of a 10 per cent solution of sodium or potassium hydroxide. Make up to one liter. Five cubic centimeters of the buffer solution added to 100 cc. of distilled water should produce a pH of about 9.8. If the pH varies more than 0.1 from this figure the buffer solution should be corrected.

2. Standard buffer solutions for pH of 9.4, 9.6, 9.8 and 10.0. These solutions should be made according to Clark and Lubs as given in "The Determination of Hydrogen Ions" by W. Mansfield Clark (Williams & Wilkins Co., Baltimore, 1923). The following mixtures are used:

pH 9.4	50 cc. M/5 H_3BO_3, M/5 KCl	32.00 cc. M/5 NaOH
pH 9.6	50 cc. M/5 H_3BO_3, M/5 KCl	36.85 cc. M/5 NaOH
pH 9.8	50 cc. M/5 H_3BO_3, M/5 KCl	40.80 cc. M/5 NaOH
pH 10.0	50 cc. M/5 H_3BO_3, M/5 KCl	43.90 cc. M/5 NaOH

Dilute each of these mixtures to 200 cc.

3. Thymol phthalein indicator. Dissolve 0.1 gram of the indicator in 250 cc. of 85 to 90 per cent ethyl alcohol. Use 0.5 cc. of the solution in 10 cc. of the buffer solution or the solution to be tested.

4. 2,6-Dibromoquinonechloroimide solution. Place about 0.02 gram of the powder in a mortar, add about 10 cc. of water, and grind until the powder is broken up very finely. Wash into a glass stoppered bottle and dilute to about 50 cc. Shake for about ten minutes and filter through paper. The solution decomposes rapidly and should not be kept for more than thirty minutes.

5. Standard phenol solution. Dissolve 10 grams of pure phenol in 1000 cc. of distilled water. Standardize against bromine or iodine. One cubic centimeter of this stock solution contains 10 mgm. of phenol. Dilute 1 cc. of the stock solution to 1000 cc. with distilled water. One cubic centimeter of the weak solution contains 0.01 mgm. The weak solution should be prepared every few weeks.

PHENOL STANDARDS

Use 100-cc. comparison tubes, preferably tubes having the 100-cc. mark about 25 cm. from the bottom. The longer tubes give a more accurate comparison when very small quantities of phenol are being tested. Add varying quantities of the weak phenol solution to comparison tubes. Standards having 0.000, 0.001, 0.003, 0.005, 0.010, 0.015, 0.020, 0.025, 0.030 and 0.040 mgm. of phenol make a convenient range. Dilute the tubes to the 100-cc. mark with phenol free distilled water. Add 5 cc. of the alkaline sodium borate buffer solution to each of the tubes. Two cubic centimeters of the 2,6-dibromoquinonechloroimide solution should be added when the distillates from the sample are ready for testing. This solution should be added to both the standards and the distillate portions at the same time.

PROCEDURE FOR MAKING PHENOL DETERMINATIONS

If the sample contains more than about 15 parts per billion of phenol, place 800 cc. of the sample in an ammonia distilling apparatus having glass stopper and mercury seal. A Maharg distilling apparatus is suitable. It would be better, of course, if 1000 cc. of the sample could be used, but most of the ammonia stills have a capacity of only about 1 liter for the flask and with the rate of evaporation desired it is not safe to put more than 800 cc. in the flask. Collect the distillate in small flasks, each having a 100-cc. mark. It is well that the end of the condenser project well into the flask so that there is very little air contact. Distill at a rate of about 8 to 10 cc. per minute. Run the cooling water through the condenser fast enough to reduce the temperature of the distillate to at least room temperature.

Evaporate five 100-cc. portions of the sample and transfer the distillate to comparison tubes with the 100-cc. mark at the same height as that of the standards. Add 5 cc. of the alkaline sodium borate solution to each of the tubes, except that it may be known from previous tests that more than 5 cc. of the solution should be added to the first 100-cc. portion. Until the characteristics of the sample are known, 10-cc. portions should be withdrawn from all the tubes, both samples and standards, and pH tests made. This should be done before the 2,6-dibromoquinonechloroimide solution is added. Add 0.5 cc. of the thymol phthalein indicator solution to each of the 10-cc. portions and the same amount of indicator to 10-cc. portions of the standard buffer solutions. Determine the pH by comparing with the standards.

If the pH is within the proper range (pH 9.6 to 10.0) and there is no variation of over 0.1 pH for the distillates and the standards, proceed with the test. Slight variations in the pH may be corrected by adding more of the buffer solution to bring the low ones up to the higher ones. If it is necessary to withdraw more than 10 cc. of the solution from any of the comparison tubes for making pH tests the entire set of tubes should be discarded and the test repeated, adding the amount of buffer solution indicated from the previous trial. After the characteristics of a sample are known it is not necessary to make pH tests. To illustrate, if a number of samples are from the same source and there is no material difference in the chemical characteristics of the samples, except possibly the phenols, the dis-

tilled portions will have the same characteristics. The withdrawal of 10 cc. from all the samples and the standards will not materially affect the phenol determination.

After all the standards, and the portions of the distillate have been buffered, add 2 cc. of the 2,6-dibromoquinonechloroimide solution. Wait at least two hours before making the comparison. The full color does not develop within this time and best results are obtained by allowing the tubes to stand over night. If this is done a stopper should be inserted in the tubes.

PHENOL RECOVERY BY DISTILLATION

All methods now in use for estimating small quantities of phenol in water supplies require the water to be alkaline. Consequently it

TABLE 1

Phenol recovery by distillation

0.016 mgm. of pure phenol added to 800 cc. of Lake Michigan water. This is 20 parts per billion. 2,6-dibromoquinone chloroimide reagent used.

DISTILLATE	PHENOL	TOTAL PHENOL RECOVERED	TOTAL PHENOL ADDED
	mgm.	*mgm.*	*per cent*
First 100 cc.	0.0035	0.0035	21.9
Second 100 cc.	0.0032	0.0067	41.8
Third 100 cc.	0.0030	0.0097	60.6
Fourth 100 cc.	0.0022	0.0119	74.4
Fifth 100 cc.	0.0020	0.0139	86.9
Sixth 100 cc.	0.0010	0.0149	93.1
Seventh 100 cc.	0.0005	0.0154	96.3

is necessary to distill the samples when more than a few parts per million of calcium and magnesium compounds are present, otherwise precipitates will occur. This includes practically all natural waters. Sodium carbonate is used in the Folin and Denis test, and sodium or potassium hydroxide is used in both the Fox and Guage and the Gibbs methods. The excellent work done by Gibbs justifies the 2,6-dibromoquinonechloroimide method being called the *Gibbs method.*

A few tests have been run in which known quantities of pure phenol were added to the Lake Michigan water. Using 800-cc. samples, the tests gave a phenol recovery of approximately 75 per cent when one-half of the solution has been distilled at a rate of

about 8 cc. per minute. When 500 cc. of the 800-cc. sample have been distilled the recovery is approximately 85 per cent. One phenol recovery test is given in table 1. These figures, while only approximately correct, have been used in computing the phenols in our work at the experimental plant. There is need for more work on phenol recovery, especially as it is the belief of a few that nearly all the phenol is recovered by distilling one-half of the sample.

If the sum of the milligrams of phenol in the first 5 portions is multiplied by 1000, divided by 0.85, and this result is divided by 0.8, it will give the parts per billion of phenol in the sample

$$\frac{0.0139 \times 1000}{0.85 \times 0.8} = 20.4 \text{ parts per billion.}$$

Should the recovery have been exactly 85 per cent for the 5 portions of distillate the recovery would have given 20.0 parts per billion, the amount added. The above figure is within the limit of errors that might be expected.

METHOD FOR CONCENTRATING PHENOLS

When less than about 10 parts per billion of phenol are present it is desirable to concentrate the phenol by distillation, although it is possible to estimate less than this amount. The concentrations may best be made by distilling 50 per cent of the solution from two or more portions of the sample. It has been shown that approximately 75 per cent of the phenol is recovered in the first 50 per cent of the distillate. Assume two 800-cc. portions of the sample evaporated one-half, and the two 400-cc. portions of the distillate combined to form another 800-cc. portion. This portion may then be distilled as previously described, collecting 100-cc. portions for testing. Should 20.0 parts per billion of phenol represent the phenol in the concentrated sample; that is, in the combination of the two 50 per cent portions of the distillate, then the phenol in the original sample is

$$\frac{20.0 \div 0.75}{2} = \frac{20.0}{1.5} = 13.3 \text{ parts per billion.}$$

This procedure may be carried any number of steps desired by dividing each previous step by 1.5. If 4 portions are concentrated to 2 portions, then the two concentrated to one 800-cc. portion, the original sample (using 20.0 as the phenol in the last concentra-

tion) would have 8.9 parts per billion of phenol. Should 20.0 represent the concentration of 8 portions of the original sample the original sample would have 5.9 parts per billion of phenol. This is about as far as is practical to concentrate. With the minimum amount that can be determined accurately in the concentrated sample it is possible to determine about 1 part per billion by this procedure of concentrating. It is possible to detect even smaller amounts, but the accuracy of the determination is doubtful.

INTERFERING COMPOUNDS APPEAR TO BE FEW

No compound, except the phenolic compounds, has been found so far that will give the characteristic blue indophenol color with the Gibbs reagent. Para cresol does not give any color and the reagent would not be satisfactory if this compound were present. Aspartic acid gives a yellow color. This compound has been found in the waste liquors from by-product coke-oven plants, and it may be responsible for the slightly yellow color that is produced in some instances. This interference is slight and probably does not interfere materially with the phenol determination. Ortho cresol seems to give a greater intensity of blue color than pure phenol. Mr. Gullans of our laboratory has given some time to studying the colors produced by the various phenolic compounds, but this work is not yet complete.

SUMMARY

A method for making phenol determinations, as suggested by Gibbs, by use of 2,6-dibromoquinonechloroimide is given.

The reagent is sensitive to 5 parts per billion of phenol, which makes it the most sensitive yet developed.

A method for concentrating the phenols so that quantities less than 5 parts per billion may be determined is also given. Approximately 75 per cent of the phenol is driven off with the first 50 per cent of the sample. Para cresol cannot be determined with this reagent. There are very few interfering compounds.

Mr. Oscar Gullans has performed practically all the tests in connection with the development of this method.

TEST FOR PHENOLIC TASTES AND ODORS IN WATER AFTER CHLORINATION[1]

At a meeting held in Pittsburgh, Pennsylvania, February 6, 1928, comprising representatives of the following:

Pennsylvania State Department of Health
Ohio State Department of Health
Kentucky State Board of Health
Carnegie Steel Company
Youngstown Sheet and Tube Company
Republic Iron and Steel Company
Jones and Laughlin Steel Corporation
Bethlehem Steel Company
United Gas Improvement Company
The Koppers Company

W. L. Stevenson, Chief Engineer of the Pennsylvania State Department of Health, Chairman of the meeting, appointed a committee to consider the test proposed by J. W. Ellms of Cleveland, Ohio, and report their opinion. The committee as appointed consists of F. W. Sperr, Jr., Director of Research, The Koppers Company; W. H. Fulweiler, Chemical Engineer, The United Gas Improvement Company; F. E. Daniels, Chief, Industrial Waste Section, Pennsylvania Department of Health; and O. O. Malleis, Chief Chemist, The Koppers Company.

The committee has considered the method as presented and is of the opinion that while in principle the method may be satisfactory for water works practice, it should be substantially modified to render it generally applicable. It is believed that in general a method of this sort should embody the principle of systematic dilutions with a test of each dilution, so that quantitative results can be secured. On this basis the committee has therefore drawn up a tentative method which is herewith submitted, not as final and binding, but for the purpose of inviting trial and comment. It is hoped that this method will be thoroughly examined and tried by all who are interested in

[1] Communications relative to the method may be addressed to F. W. Sperr, Jr., Mellon Institute, Pittsburgh, Pa.

the subject, and the committee would appreciate having reports of the results obtained together with any suggestions for modification or improvement that may be considered necessary.

The tentative method proposed by the committee is as follows:

1. This test is designed as a measure of the so-called phenolic tastes and odors in water after chlorination.

2. Take 500 cc. of the material under examination, acidulate with sulphuric acid until acid to litmus, and distil off 250 cc. Catch the distillate in a 500 cc. volumetric flask, make up to mark with distilled water and dilute as follows: 1 to 10; 1 to 100; 1 to 1000; etc., preparing as many dilutions as may be necessary.

3. Take 200 cc. of the distillate in the volumetric flask after making up to mark (this representing the original material undiluted) and a like amount of each successive dilution. Treat with a slight excess of chlorine water (a total of 0.3 p.p.m. of chlorine is usually sufficient). Let the sample stand for fifteen minutes and then boil until excess of chlorine is removed as evidenced by test with orthotolidin.

Make the odor test by smelling the hot liquid. Make the taste test after the liquid is cooled. In the taste test, swallowing a small quantity of the liquid is the best method for revealing the presence of taste producing substances.

4. Results shall be expressed as the lowest dilution in which the taste and the odor are negative.

F. W. Sperr, Jr.,
W. H. Fulweiler,
F. E. Daniels,
O. O. Malleis.
Committee.

VOLUMETRIC METHOD FOR DETERMINATION OF SULFATE ION

By Frederick G. Germuth[1]

The gravimetric determination of sulfates by the familiar method of precipitation by barium chloride is characterized by several undesirable features which numerous painstaking researches meticulously carried out have been unsuccessful in eliminating. Of these the most pronounced is, perhaps, the tendency of the barium sulfate precipitate to occlude barium chloride and other compounds that may be present in the form of impurities, thereby introducing a source of error, the extent of which is too frequently minimized.

It has been shown[2] that occlusion does not occur as readily when precipitation is made in cold (20°C.) solutions as when the barium chloride solution is added for this purpose to solutions which possess the temperature of their boiling-points.

Unfortunately, the former procedure requires a greater amount of time for completion, with the ensuing tendency to restrict its employment to work of an experimental character in which a higher degree of accuracy is of paramount importance, rather than to routine analytical tests in which ease and speed of manipulation are essential.

Of the comparatively few volumetric methods extant for this specific estimation, that of Wildenstein[3] is generally conceded to be most applicable and to insure greatest satisfaction where the concentration of SO_4 ions is somewhat high. This method advocates the use of 0.25 N $BaCl_2$ solution, 1 cc. of which is chemically equivalent to 0.01 gram SO_3. It is apparent that the method under discussion is inadequate and does not admit of application where the determination of minute quantities of sulfates are to be considered.

Furthermore, precipitation of the $BaCrO_4$ on addition of the chromate solution employed is accomplished at the boiling-point of the

[1] Chemist, Department of Public Works, Bureau of Standards, Baltimore, Md.

[2] Germuth, American Journal of Pharmacy, Vol. 99, No. 5.

[3] Wildenstein, Volumetric Analysis, Sutton, 10th Edition, page 350.

solvent, and subsequently, an additional length of time is required to enable the precipitate of $BaCrO_4$ to settle. It is a recognized fact that this compound is far more soluble when precipitation occurs at elevated temperatures. In the interest of accuracy it is imperative that this procedure take place when the temperature of the solution under examination is that of the laboratory, i.e., about 20°C.

The author believes the reasons considered furnish sufficient grounds for the promulgation and employment of the method here presented for the volumetric determination of sulfates, particularly where the amount present in the material under analysis is small, as in the estimation of SO_3 in potable waters, and determination of the combined radicle contained in sera and other body fluids, frequently obtaining in normal as well as pathological conditions, encountered in clinical laboratory tests.

METHOD

Precipitation is accomplished by adding a slight excess of 0.02 N $BaCl_2$ slowly (while stirring vigorously) to the solution of the sulfate, or substance containing sulfate, slightly acidified with HCl, at room temperature. After this has stood for five minutes, 5 per cent NH_4OH is then added to alkalinity, employing phenolphthalein as indicator, and then 10 cc. of 0.5 per cent $CH_3COO{\cdot}NH_4$ solution. 0.02 N K_2CrO_4 is next run in from buret until an additional drop of this reagent produces the characteristic color caused by the formation of $PbCrO_4$ when placed in contact with a drop of 5 per cent Pb $(NO_3)_2$ solution contained on a white, waxed porcelain tile, constituting the outside indicator. When titration is carried out at room temperature, it may be necessary to allow several minutes to elapse in order for the precipitate to settle.

SOLUTIONS EMPLOYED IN DETERMINATION

0.02 N $BaCl_2$ solution contains 4.8860 grams of $BaCl_2{\cdot}2H_2O$ per liter; 1 cc. of which is chemically equivalent to 0.0041 gram $BaSO_4$.

0.02 N K_2CrO_4 solution contains 3.8880 grams of K_2CrO_4 per liter; 1 cc. of this is equivalent to 0.0049 gram of $BaCl_2{\cdot}2H_2O$, i.e., the amount of $BaCl_2{\cdot}2H_2O$ contained in 1 cc. of the 0.02 N $BaCl_2$ solution used.

Five per cent solution of $Pb(NO_3)_2$.

STANDARDIZATION

Standardization of the 0.02 N $BaCl_2$ is accomplished by adding a slight excess of the solution to a known volume of 0.02 N H_2SO_4, and the excess de-

termined by 0.02 N K_2CrO_4, in the manner described. In this way the $BaSO_4$ value per cubic centimeter of solution is ascertained. The relation existing between the $BaCl_2$ and the K_2CrO_4 is determined by adding the latter to a known amount of the former until the yellow coloration is formed upon adding a drop of solution to the outside indicator of $Pb(NO_3)_2$.

In this manner the amount of $BaCl_2 \cdot 2H_2O$ represented by 1 cc. of the K_2CrO_4 is obtained. To effect ease of manipulation and subsequent calculation, it is considered desirable to make the necessary correction, and so adjust the K_2CrO_4 solution that 1 cc. of this will react quantitatively with a like volume of the $BaCl_2$ solution employed as precipitant.

SELECTION OF OUTSIDE INDICATOR

Experiments made supported the view that lead nitrate serves as a better outside indicator than silver nitrate, for, aside from the fact that the latter is more costly, with its usage insoluble silver chloride is produced. This tends to obscure the coloration eventually produced by potassium chromate, and renders the end-point less readily discernible. When the use of lead nitrate is resorted to, this specific disadvantage is eliminated, the solubility of lead chloride preventing the production of more than a slight turbidity.

SUMMARY

A method for the volumetric determination of minute portions of sulfates occurring in water, body fluids, etc. has been presented, in which the inherent error of the older gravimetric method caused by occlusion of the precipitating agent by the precipitate of barium sulfate, is greatly inhibited, or entirely obviated.

In addition to insuring a high degree of accuracy superior to that of the method commonly employed, a considerable saving in time is effected.

When the determination is made under the conditions exploited, quantitative results are assured.

PROGRESS REPORT ON WORK OF AMERICAN ENGINEERING STANDARDS COMMITTEE SECTIONAL COMMITTEE ON STANDARDIZATION OF PIPE FLANGES AND FITTINGS

As representative of the American Water Works Association, on the American Engineering Standards Committee on Standardization of Pipe Flanges and Fittings, I am submitting brief progress report as of some interest to the membership.

The work of the A.E.S.C. Sectional Committee on Standardization of Pipe Flanges and Fittings has been divided into the following projects:

1. Malleable Iron Screwed Fittings Stds., 150 pounds W.S.P.
2. Cast Iron Screwed Fittings Stds., 125 pounds W.S.P.
3. Cast Iron Screwed Fittings Stds., 250 pounds W.S.P.
4. Cast Steel Flange Stds., 250 pounds W.S.P.
5. Cast Steel Flange Stds., 400 pounds W.S.P.
6. Cast Steel Flange Stds., 600 pounds W.S.P.
7. Cast Steel Flange Stds., 900 pounds W.S.P.
8. Cast Steel Flange Stds., 1350 pounds W.S.P.
9. Cast Steel Flange Stds., 2000 pounds W.S.P.
10. Cast Steel Flange Stds., 3200 pounds W.S.P.
11. Cast Iron Flange Stds., 125 pounds W.S.P.
12. Cast Iron Flange Stds., 250 pounds W.S.P.
13. Cast Iron (Screwed and Flanged) Long Turn Sprinkler Fittings Stds.
14. Cast Iron Flange Standards for Pressures under 100 pounds W.S.P.
15. Ammonia Fittings (Flanged and Screwed) Standards
16. Steel Screwed Fittings Standards
17. Non-Ferrous Screwed Fittings Standards
18. Center to Face Dimensions of Ferrous Flanged-end Valves

Projects Nos. 1 to 8 inclusive are completed, having been approved by the A.E.S.C. as Tentative American Standards and are available in pamphlet form.

Projects Nos. 11 and 12 are practically finished, and following a few minor changes, will also be printed as Tentative American Standards.

Projects Nos. 13 and 14 will in the near future be presented by the Sectional Committee to the Sponsors for approval, following which

they will be submitted to the A.E.S.C. for final approval and promulgation as Tentative Standards.

Projects Nos. 9, 10 and 15 can be reported simply as in process.

Projects Nos. 16 and 17 will be taken up by the Committee as soon as time permits.

Project No. 18 has been recently added to the scope of the Committee and has only been given brief consideration as yet.

Respectfully submitted,

F. A. BARBOUR, *Representative, A. W. W. A.*

SOCIETY AFFAIRS

INDIANA SECTION

The twenty-first annual meeting of the Indiana Section met at Purdue University, Lafayette, Indiana, on March 15 and 16, 1928. At every turn, from the time of arrival and registration until actually leaving the campus, the members were aware of the care, thought and foresight of the University, through its Engineering Extension Department, in charge of Prof. W. A. Knapp, which helped make the meeting one of the best and most pleasant experienced in the twenty years of its existence.

Mr. George W. Fenkell, General Manager, Department of Water Supply, Detroit, presented a paper on "Elevated Water Storage."[1] Fire protection as an important part of the service supplied by the water plant was stressed by F. C. Jordan, Secretary of the Indianapolis Water Company. Water works men were urged to maintain close touch with the fire fighting agencies of their communities and to keep before them and the public the importance of water in fighting fires. No agent has been developed or produced which is so universally effective in fire fighting as is water. Often a manufacturer or building owner feels that he is indebted to the sprinkler system for extinguishing a fire, disregarding the rôle played by the water delivered through the sprinkler. In the paper and in a discussion by George W. Fenkell, the managers were urged to make careful surveys to learn the capacity of their systems in localities of special danger or high value. Mr. Fenkell described clearly and in detail the method of procedure with the use of pitometers to determine the amount of water available in a district.

The service performed by the State Water and Sewage Department in assisting in the protection of public water supplies was outlined by Lewis S. Finch, Director. Several specific instances were given in which contamination was discovered and traced to

[1] Journal, April, 1928, page 347.

poorly sealed casings, contaminated surface water and leaky sewers near tile collecting lines.

Many water works men operate power plants as well, and to them, especially, the paper by J. C. Henninger, was interesting. Following the paper describing the power plant at Purdue University, of which Mr. Henninger is Chief Engineer, many of the members accepted an invitation to visit and inspect the plant.

At the dinner Dr. A. A. Potter, Dean of the School of Engineering, told of the work of the University in its relation to the industries of the State. Many large research problems are being carried on through a coöperative arrangement between the University and private interests. One such project involves the expenditure of $100,000.00 on the part of the industry.

Mr. Beekman C. Little, Secretary of the American Water Works Association, discussed the relation between the parent organization and the various sections. The organization has grown to such an extent that regional meetings are suggested to take the place of the general national meeting as now arranged. Although this will increase the work of the national officers and the cost it is felt that a larger number of members would be able to attend. While no serious criticisms were made on specific points in the Manual of Water Works Practice, it was felt that it might be made to include more material suitable for the use of the operator of a small plant. It is recognized by the meeting that the Manual is accepted generally as authority on water works matters and the section desires to be of assistance in making it valuable to the greatest number.

Mr. W. C. Mabee, Chief Engineer of the Indianapolis Water Co., reported a very extensive investigation of "Unaccounted for Water" at Indianapolis. In connection with this study data were obtained from many other cities. It was found that unaccounted for water varied in different cities from 5 to 60 per cent, with an average of 25 per cent of the total pumped.

Investigation of the Surface Water Flow in Indiana was reported by Denzil Doggett, Assistant State Engineer. The Department of Conservation is establishing stations on the streams of the state as fast as men and money are available. Daily gage reading are obtained by coöperation with individuals living near the points under observation. Many stations are now established and are yielding valuable data in the study of the possible organic load from cities and industries, as pointed out by John C. Diggs, of the Department of Conservation, in his discussion of the paper.

Charles P. Hoover, Chemist in Charge, Columbus, Ohio, Water Purification Plant, read a paper on "Water Softening for Small Cities" in which he demonstrated its feasibility. For twenty years the Columbus water has been softened satisfactorily and with the advance in the art many other cities are building plants for the purpose of softening the entire supply. Thirteen such plants are in operation in Ohio. Mr. Hoover has found that a hardness of 120 p.p.m. causes complaint on the part of the consumer, while one of 90 p.p.m. seems to be satisfactory to most people. He advises that plants effect a removal of hardness to a point between 70 p.p.m. and 80 p.p.m. and that it be held fairly constant, since variations are noted by the user and complaints result.

Dean Mary L. Matthews, of the School of Home Economics, gave a very pleasing talk on "The Domestic Convenience of Water" in which she stated that her investigations have shown that running water is placed before most other modern conveniences by women living in rural districts.

The afternoon session on the 16th was devoted to Round Table discussion of the topics including power plant operation, meter accuracy and reading, use of flushometer valves, and services in advance of street improvement. In the discussion of the cost of service connections it developed that, in general, publicly and privately owned plants are governed by quite different methods of procedure. The former make a rather moderate flat charge for placing the service and the charge is not refunded nor applied to future bills. The privately owned plant makes a somewhat higher charge at the time the service is placed and refunds it when actual service is established, or it is applied to bills for water furnished. In either case the service is considered to be a part of the utility plant.

The meeting was well attended by representative water works men of the state with a number of engineers and city officials interested in the problems of the water departments.

The officers elected for the year 1928–1929, follow:

President, C. E. Stewart; Vice President, I. L. Miller; Secretary-Treasurer, C. K. Calvert; Assistant Secretary, L. S. Finch.

Executive Committee: John W. Moore, J. F. Bradley, Howard Dill, Earl Carter, George Waldrop, H. S. Morse, W. L. Younce, F. T. Schultz and J. W. Malott.

REPORT OF THE RESOLUTIONS COMMITTEE

This is the twenty-first annual meeting of the water works men of the state of Indiana. With the years of pleasant association in retrospect, we offer our thanks to those men who sensed the value of such an organization and look forward to future years of useful contacts in these meetings.

We are grateful to the engineering faculty of Purdue University for the courtesies shown us by providing an adequate meeting place and assisting in the program. To them we are deeply indebted.

We appreciate the valued service of the departments of the State organized to conserve the water supplies and guard the health of the citizens. We pledge them our support in every forward looking movement they undertake.

The Indiana Section of the American Water Works Association is vitally interested in any measure which will make possible the prevention and suppression of disease, and

The United States Public Health Service, through its research and other activities, has accomplished much of value not only to prevent disease, but also to advance the science of water purification, and

A Bill (S-3356) has been introduced in the United States Senate providing for further coördinating the public health activities of the Federal Government, to the end that the United States Public Health Service may more effectively carry on and extend its splendid work, therefore be it

Resolved that the Indiana Section of the American Water Works Association does hereby endorse the proposed legislation (S-3356) and (H. R. 11026) and instructs its Secretary to forward a copy of this resolution to each of the United States Senators, representing Indiana.

Signed H. E. Jordan
F. P. Stradling
George Waldrop
C. K. Calvert,
Secretary-Treasurer.

ABSTRACTS OF WATER WORKS LITERATURE[1]

FRANK HANNAN

Key: American Journal of Public Health, **12**: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Passivity and Corrosion of Iron. LEON MCCULLOCH. Trans. Am. Electrochem., Soc., **50**: (preprint), 10 pp., 1926. From Chem., Abst., **20**: 3438, November 10, 1926. Two new instances of passivity in iron described. An addition is attempted to current theory of corrosion of iron. Progressive rusting of iron is ascribed to "catalytic" action of soluble iron salts, which are held upon the iron surface by the coating of rust. These soluble iron salts are product of electrolytic action which takes place over surface of metal when exposed to natural waters and air. Thus the modern electrolytic theory and old acid theory are combined into one, but carbon dioxide to which corrosion was attributed by old acid theory is no longer necessary, since iron salts of stronger acids are seen to be present.—*R. E. Thompson.*

Tests of Some Rust-Preventing Materials Suitable for the Protection of Stored Machinery. C. JAKEMAN. Engineering, **120**: 123–5, 1925. From Chem. Abst., **20**: 3439, November 10, 1926. Commercial preparations which were more of nature of paints were not found as effective in preventing formation of rust as application of grease. Thick coating of lanolin was fairly satisfactory but better protection was obtained by using solution containing about 23 per cent of lanolin or wool grease. Paraffin oil, light petroleum, benzene and gasoline were found to be suitable solvents, latter being particularly satisfactory except for its inflammability.—*R. E. Thompson.*

The Use of the Bicolorimeter for the Estimation of Hydrogen-Ion Concentration. V. C. MYERS and L. E. BOOHER. Proc. Soc. Exptl. Biol. Med., **22**: 511–2, 1925. From Chem. Abst., **20**: 3468, November 10, 1926. Acid and alkaline wedges are prepared for each of following indicators: phenol red, bromocresol purple and bromocresol green (or methyl red), ranges being 6.6–8.6, 5.2–7.0 and 4.6–5.4. Preparation and calibration of wedges described. Method has color comparison error of $\pm$ pH 0.02 to 0.04.—*R. E. Thompson.*

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[1] Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

Cellobiose Fermentation by Coli-Aërogenes Group. S. A. Koser. J. Infectious Diseases, 38: 506–10, 1926. From Chem. Abst., 20: 3480, November 10, 1926. In fermentation of cellobiose, an uncommon sugar considered to be 5-glucose glucoside, differentiation of intestinal B. coli from aërogenes-cloacae groups is quite distinct. Correlation between all tests is not obtained with so-called intermediate forms obtained from soil.—*R. E. Thompson.*

A New Process for Coating (Iron) with Lead. Hugo Krause. Apparatebau 38: 200–1, 1926; cf. C. A., 20: 2648. From Chem. Abst., 20: 3440, November 10, 1926.—*R. E. Thompson.*

Steel Protective Method. J. D. Klinger and C. L. Boyle. Can. 261, 218, June 1, 1926. From Chem. Abst., 20: 3442, November 10, 1926. Method of cleaning steel and imparting thereto rust-inhibitive properties consists in treating it with solution containing sulfuric acid, a soluble chromate, an alcohol, and acetone.—*R. E. Thompson.*

Examination of Sources for Water Supplies. New Methods of Treating Waters. Peter. Mitt. Lebensm. Hyg., 17: 159, 1926. From Chem. Abst., 20: 3523, November 10, 1926. Ground water flow may be estimated from rainfall and drainage area. A good spring does not change in temperature or quantity of flow throughout seasons. Common methods of filtration and sterilization described.—*R. E. Thompson.*

The Drinking Water Supplies of Dutch East Indies. Jan Smit. Z. angew. Chem., 39: 961–2, 1926. From Chem. Abst., 20: 3523, November 10, 1926. Principal cities are now using water from deep wells, mountain streams, impounding reservoirs, and rivers. Filtration is new and little used. Chlorination is employed at some places. Research laboratory has been established at Batavia to study water and sewage problems.—*R. E. Thompson.*

Geological Surveys for Water Supplies. J. Hug. Mitt. Lebensm. Hyg., 17: 169, 1926. From Chem. Abst., 20: 3523, November 10, 1926. Description of series of typical water-bearing strata.—*R. E. Thompson.*

Statistics of Water Tests (Germany). K. Thumm. Gas- u. Wasserfach 69: 753–9, 1926. From Chem. Abst., 20: 3523, November 10, 1926. Composition, acidity, etc., of various water supplies listed and discussed.—*R. E. Thompson.*

Recording "Dionic" Water-Testing Apparatus. Engineering, 121: 773, 1926. From Chem. Abst., 20: 3523, November 10, 1926. Instrument measures total dissolved solids. It is sensitive to small quantities.—*R. E. Thompson.*

Chlorination and Chlorine-Binding Power of Water. A. Massink. Chem. Weekblad, 23: 329–34, 1926. From Chem. Abst., 20: 3524, November 10, 1926. Lecture dealing with results of Wolman (C. A., 13: 1111), which have been corroborated. Determination of chlorine with o-tolidin discussed, with

particular reference to effect of pH. Variable chlorine dose found advisable (cf. HALE, C. A., 17: 1853).—*R. E. Thompson.*

Sulfur Bacteria as Indicators of Polluted Waters. DAVID ELLIS. Engineering, 122: 231, 1926. From Chem. Abst., 20: 3525, November 10, 1926. Beggiatoa alba, a motile, sulfur-containing, cylindrical filament about 2μ in thickness and a few μ to $\frac{1}{5}$ mm. in length, appears as grayish white felty covering on bed of stream or pool. In clear water this organism is indicator of sewage pollution, but in water containing decomposing organic matter growth is probably due to the presence of this material.—*R. E. Thompson.*

Soluble Alkalinity of Waters Used in Spinning and New Method for Determining It. GIOVANNI BARONI. Giorn. chim. ind. applicata, 7: 137–40, 1925. From Chem. Abst., 20: 3524, November 10, 1926. Method is as follows: Into 750-cc. flask of neutral glass introduce 300 cc. of the water. Heat to boiling for 1 hour under reflux condenser, avoiding concentration of liquid, aspirating through it a current of air freed of carbon dioxide by previously passing through sodium hydroxide. Cool flask rapidly by immersing it, without removing it from apparatus, in vessel containing circulating water. Stop aspiration; allow to stand 15 minutes. Draw out liquid from flask by means of siphon, filter through dry filter and collect in 250-cc. volumetric flask. Pour into 750-cc. beaker rinsing, with little water, add 1 cc. of 1 per cent phenolphthalein solution, boil briskly and titrate with 0.1 N sulfuric acid until pink color does not reappear with prolonged boiling. Titration should take $\frac{1}{2}$ hour. Multiply amount of sulfuric acid used by 4 to obtain soluble alkalinity per liter or express in degrees (1 degree = p.p.m. sodium carbonate) by multiplying cc. sulfuric acid used by 5.3. As check run blank using recently boiled water, to obtain error due to boiling for corresponding time in apparatus. Method is simpler and gives more constant results than old method, and there is greater correlation with degree of alkalinity which the water assumes in treating basins.—*R. E. Thompson.*

Artesian Wells of the Christchurch Area. F. W. HILGENDORF. Trans. Proc. New Zealand Inst., 56: 369–82. 1924. From Chem. Abst., 20: 3523, November 10, 1926. Water level rises with rain, but amount of rise and period between rain and rise depend greatly on previous weather. Percolation from adjoining river prevents level falling below normal.—*R. E. Thompson.*

New Filtration Plant at Walton on Thames. Engineer, 142: 109–12, 134–6, 161–4, 1926. From Chem. Abst., 20: 3524, November 10, 1926. Illustrated description.—*R. E. Thompson.*

Water Purification by the Electroösmotic Process. VON BEZOLD. Brennstoff und Wärmewirtschaft, 8: 242–5, 1926. From Chem. Abst., 20: 3524, November 10, 1926. Examples of complete purification by electroösmosis given, conductivity of product being approximaely that of commercial distilled water (1.5×10^{-5}). Power consumption is about 2 kw.-hr. per 100 liters

of water containing 20 grams of salts per 100 liters, voltage employed being 110–220 d.c.—*R. E. Thompson.*

Modern Water Degasification Processes. W. Steinmann. Gas- u. Wasserfach **69**: 691–4, 1926. From Chem. Abst., **20**: 3524, November 10, 1926. Conditions under which vacuum process for removing carbon dioxide from hard waters is applicable are discussed.—*R. E. Thompson.*

Oswestry Filter Beds of the City of Liverpool Waterworks. Engineering, **122**: 123, 1926. From Chem. Abst., **20**: 3525, November 10, 1926. Water is aërated before it reaches new filters in order to relieve filter beds by pre-oxidation of organic matter and to convert ferrous to ferric salts. Aëration and filtration reduce color from 6.5 to 3–3.5. Filtration alone reduces color to 3.5.—*R. E. Thompson.*

Studies of Water Purification. IV. The Adsorption of Neutral Salts by Kambara Earth. Shu Oikawa. J. Biochem. (Japan), **6**: 117–28, 1926. From Chem. Abst., **20**: 3525, November 10, 1926. Tests with Kambara earth show that Cl^{-}_{4} and SO^{--} adsorbed from neutral salts. Calcium is adsorbed sufficiently to make possible the use of the earth for softening water. Adsorption of salts is not so great as that of acids. In mixture of both, the adsorption of salt is hindered while that of acid is, generally, increased.—*R. E. Thompson.*

Data on Zeolite Water Softeners. T. J. Ess. Power Plant Eng., **30**: 888, 1926. From Chem. Abst., **20**: 3758, November 20, 1926. Formulas for calculation of size of softener required.—*R. E. Thompson.*

The Biological Purification of Unfermented and Fermented Sulfite Waste Liquors. Arno Müller and Max Müller. Arb. Reichsgesundh., **57**: 573–9, 1926; cf. C. A., **8**: 3857; **13**: 1531. From Chem. Abst., **20**: 3526, November 10, 1926. Determination of nitrate content or oxygen consumption is not adapted for following biological purification of mixtures of city sewage and fermented or unfermented sulfite waste liquor. Sewage from city of Berlin, whether treated with approximately 10 per cent unfermented, or 15 per cent, fermented, liquor, was still purified biologically. These values may possibly be increased somewhat by using more completely neutralized liquor.—*R. E. Thompson.*

Water Purification. T. R. Duggan. Can. 258, 614, March 2, 1926. From Chem. Abst., **20**: 3526, November 10, 1926. First portion of salt used for regenerating exchange silicates is discarded and a later portion segregated and all or some of lime and magnesia removed to render it suitable for reuse.—*R. E. Thompson.*

A Calculation of the Contamination of (German) Streams by Potash Waste Waters. W. Kerp and E. Merres. Arb. Reichsgesundh., **57**: 522–30, 1926. From Chem. Abst., **20**: 3540, November 10, 1926. Contamination of Middle Weser District is recalculated on basis of present ore composition and increase

noted in hardness and chloride content as compared with corresponding values given in Middle Weser decision, part 2.—*R. E. Thompson.*

Recovery of Phenols from Gas Liquors. R. M. Crawford. Blast Furnace and Steel Plant, **14**: 400–1, 1926. From Chem. Abst., **20**: 3557, November 10, 1926. Operation of Troy, N. Y., plant (cf. C. A. **20**: 1313) for continuous extraction of phenols from gas liquors by benzol has been continuous and successful. The sodium hydroxide solution used to extract phenols from benzol is now neutralized with sodium bicarbonate (instead of with carbon dioxide or sulfuric acid) and spent soda solution obtained is used in Seaboard liquid gas purifying unit, efficiency of latter being increased.—*R. E. Thompson.*

The Effect of Anions Upon the Physical, Chemical, and Colloidal Properties of Aluminum Hydroxides. L. B. Miller. Third Colloid Symposium Monograph 1925, 208–15; cf. C. A. **19**: 1465. From Chem. Abst., **20**: 3610, November 20, 1926. This research indicates that in water purification by alum 3 chemical factors determine success: (1) certain minimum amount of aluminum ion; (2) anion of strong coagulating power; (3) properly adjusted pH. Of all anions studied, SO_4^{--} yields floc with qualities best suited to water clarification, it being rapid-settling and compact. The pH range over which aluminum sulfate is thus effective (5.3–8.7), with maximum at 5.5) is much broader than that of aluminum chloride (7.8–8.6). Precipitate which separates when an aluminum salt in dilute solution is treated with alkali is not aluminum hydroxide (except perhaps at relatively high pH values) but a more complex substance containing varying proportions of anions present in solution.—*R. E. Thompson.*

Vapor Pressure and Base Exchange of Zeolites and Permutites. V. Rothmund. Z. Elektrochem., **32**: 367–71, 1926. From Chem. Abst., **20**: 3613, November 20, 1926. Discussion of characteristics, properties, and uses of zeolites, with special reference to waterholding and base exchange. These substances hold water in same way as gels and not as hydrated salts, since water molecules take no essential part in crystal structure. Base exchange formula given.—*R. E. Thompson.*

Method for the Colorimetric Determination of Ferric Ion, Applicable Also to Strongly Acid Solutions. H. W. van Urk. Pharm. Weekblad, **63**: 1121–3, 1926. From Chem. Abst., **20**: 3661, November 20, 1926. Color reaction with pyramidone is applicable to determination of ferric iron in dilute acid solution (sulfuric). At 0.1 N acid, color is dependent on acid concentration, but at 0.2 N and beyond this, acid concentration has little influence. Good results are obtained with 0.05–0.03 mgm. ferric iron per 100 cc. Determination is best performed with 1 per cent pyramidone but lower concentrations down to 0.1 per cent may be used.—*R. E. Thompson.*

Air Heating in the Steam Boiler Plant. Schlicke. Die Wärme, **49**: 368, 1926. From Chem. Abst., **20**: 3553, November 10, 1926. Air preheater was inserted after economizer in old boiler plant with circulation boiler of 450

square meters heating surface and 15 square meters of traveling grate surface. Air heater, which had heating surface of 420 square meters, was inserted so that flue gases passed through vertically and air horizontally. Gases were cooled from 240 to 150°; air was heated from 20 to 115°. Total boiler efficiency was increased 3.5–4 per cent, equal to saving of about 5 per cent of coal. Furthermore boiler pressure increased 15 per cent. A 25 per cent faster initial combustion was noted. Possible difficulties discussed and means of elimination suggested. Corrosion of wrought-iron heater could not be detected after 1½ years' operation.—*R. E. Thompson.*

Removing Phenols from Waste Waters, etc. P. Preiss. Brit. 241, 682, September 19, 1924. From Chem. Abst., **20**: 3559, November 10, 1926. Phenol and its homologs are removed from waste waters, etc., by solvents in vapor form, e.g., benzol or benzine, applied countercurrentwise in scrubbing tower.—*R. E. Thompson.*

Filter for Water or Other Liquids. T. Linke. U. S. 1,603,126, October 12. From Chem. Abst., **20**: 3593, November 20, 1926.—*R. E. Thompson.*

Production of Hydrogen by Steam in a Hot Boiler Tube. J. Porter. Roy. Tech. Coll. Glasgow, 1925, 2, 14–18; Sci. Abstract, **29B**: 106. From Chem. Abst., **20**: 3623, November 20, 1926. Short account of action of steam on iron. Experiments described which show (for particular case of action of stagnant steam on boiler tube) rapid increase rate at which this action takes place when temperature is raised to or above 900°F.—*R. E. Thompson.*

The Carbon Dioxide Content of Distilled Water and Its Determination. I. M. Kolthoff. Chem. Weekblad, **23**: 381–4, 1926. From Chem. Abst., **20**: 3613, November 20, 1926. In titration of carbon dioxide as monobasic acid, endpoint is reached after complete conversion to HCO_3^-. Kolthoff uses phenol red as indicator—100 mgm. in 4.5 cc. 0.1 N alkali, made up to 100 cc. with water. Jena-glass flask is filled with 1 to 1.3 liters of the water, 1 cc. indicator added and then 0.01 N sodium carbonate from buret until red-violet color remains 5 minutes. Between each addition flask is closed and shaken. Values of up to 2.4×10^{-4} M (10.56 p.p.m.) were found for distilled water. After air was passed through for 10 hours value became 1.55×10^{-5}, M (0.68 p.p.m), theoretical value being 1.5×10^{-5} M (0.66 p.p.m.). On standing equilibrium was reached only after 1 week.—*R. E. Thompson.*

Presence of Air in Pure and in Alkaline Water. J. Porter. J. Roy. Tech. Coll. (Glasgow), **2**: 19–25, 1925. From Chem. Abst., **20**: 3613, November 20, 1926. When pure water is heated to 100° it still retains about 11 cc. air per liter, and this is removed only by prolonged boiling. Addition of 4 grams sodium hydroxide per liter increases rate of evolution at temperatures above 60° and air retained at 100° is only 4.8 cc. per liter. Solubility of air in 4 per cent sodium hydroxide at 17° is 8 cc. per liter, compared with 20.4 cc. in pure water. Very little air is evolved on heating until temperature above 80° is reached, and experiments indicate that air so retained forms layers of no

appreciable volume on sides of vessel and is not held in supersaturated solution. If water is maintained for prolonged period at temperature of 60°, however, all excess air over amount that will remain in solution at that temperature is slowly liberated. Addition of slight amount of oil to water during heating causes more regular evolution of dissolved air.—*R. E. Thompson.*

Corrosion. H. Zurlinden. Wochbl. Papierfabr., **57**: 747–9, 1926. From Chem. Abst., **20**: 3680, November 20, 1926. Modern corrosion theories briefly discussed. Dissolved oxygen in water can be removed by (1) heating, (2) vacuum, and (3) chemical combination with specially prepared manganese-steel.—*R. E. Thompson.*

Construction of Stable Colorimetric Scales for Measuring pH Values. P. Bruère. J. pharm. chim., **8**: 3, 377–9, 1926. From Chem. Abst., **20**: 3660, November 20, 1926. Permanent standards for range 6.0–7.6 for use with bromothymol blue are described.—*R. E. Thompson.*

A New Method for Quantitative Sampling of the Sea-Bottom. O. D. Hunt. J. Marine Biol. Assoc., **14**: 529–34, 1926. From Chem., Abst., **20**: 3709, November 20, 1926. The "Vacuum Grab," a metal chamber hermetically sealed by glass diaphragm, is lowered to bottom, where diaphragm is automatically broken. Pressure of overlying water forces into chamber a sample of bottom, which is prevented by "trap" device from escaping when apparatus is raised.—*R. E. Thompson.*

The Flow of Air and Steam in Pipes. W. H. McAdams and T. K. Sherwood. Mech. Eng., **48**: 1025–9, 1926. From Chem. Abst., **20**: 3757, November 20, 1926. Equations and curves in units convenient for engineering calculations.—*R. E. Thompson.*

The Lead Mine as an Active Agent in River Pollution. K. E. Carpenter. Ann. Appl. Biol., **13**: 395–401, 1926. From Chem. Abst., **20**: 3758, November 20, 1926. Effect of lead mine waste upon fauna of a stream described. Inefficiency of careful sedimentation in removing toxic matter from lead mine waste is indicated. Two remedies suggested: (1) reduction of solvent action of water on lead by use of silicates and (2) elimination of dissolved metals in waste by suitable filters before discharge.—*R. E. Thompson.*

Winkler's Method for Determining the Oxygen Dissolved in Water and Its Application in the Presence of Oxidizable Substances. Gustaf Alsterberg. Biochem. Z., **170**: 30–75, 1926; cf. C. A., **20**: 790. From Chem. Abst., **20**: 3760, November 20, 1926. Following precautions should be observed; Manganese chloride solution should be free from iron and sample should not be left standing longer than 15 minutes after addition of reagents. If determination cannot be completed at once, sample should at least be acidified. The 0.01 N thiosulfate solution should be standardized with potassium iodate and not by potassium bichromate. Original method is not applicable to water containing impurities. Modifications proposed by Winkler are worthless because they

assume that losses in oxygen occur during process of acidifying whereas most interfering substances tend to reduce oxidized manganese hydrate precipitate in the alkaline medium. Washing precipitate is useful only in presence of nitrite; hydrogen sulfide, sulfur dioxide, iron, and organic substances not being affected. Preliminary oxidation with potassium permanganate causes large errors as this activates dissolved oxygen, giving it greater tendency to directly oxidize organic substances present. Iron compounds can be made inactive only with great difficulty. Even presence of nitrites necessitates preliminary treatment. Sample should be treated with free bromine, excess being reduced with salicylic acid. About 0.5 cc.N bromine is sufficient for 125-cc. sample. After adding bromine allow to stand 24 hours, add 0.5 cc. salicylic acid reagent and carry out usual procedure after 15 minutes. Interference of iron (ferrous iron has most serious effect causing losses, while ferric iron causes too high results) is entirely eliminated by using phosphoric acid. Hydrogen sulfide is one of most common and serious interfering substances but is completely oxidized by bromine in 24 hours. Nitrites are almost immediately converted to nitrates by bromine. Conversion of interfering ferrocyanide to much less interfering ferricyanide is added advantage, besides its actual preserving action. Bromine may cause high results in presence of cyanides or thiocyanates as it will be in combination not acted upon by salicylic acid. Correction for this has not been devised.—*R. E. Thompson.*

How to Increase Ground Water Supplies. W. G. Kirchoffer. Water Works Eng., **80**: 15, 1076, July 20, 1927. Deals with water supplies derived from wells, both deep and shallow. Describes method of increasing water supplies from (1) wells in rock formation; (2) wells in loose formations, but relatively deep and of small diameter; (3) wells in a fine sand overlaid by impervious materials, water under pressure sufficient to produce a flow or raise the water near the ground level; (4) wells in shallow formations of loose materials, such as sand and gravel and of relatively large diameters; (5) springs from rocks; (6) springs or seeps from shallow formations; (7) sub-surface dams across valleys.—*Carl Speer, Jr.*

Surveys, Meters, and Good Service Keep Water Rates at Low Level. W. C. MacDonald. Water Works Eng., **80**: 15, July 20, 1927. Water waste surveys in Ottawa, Canada, reduced water consumption in 1918 of 217 gallons per capita to 159 gallons per capita in 1926. Unfair to sell supply of water other than by meter. Necessary for water department to coöperate with public by giving efficient service. Must safeguard comfort and convenience and protect the lives and property of the citizens which it serves. Most recent device is an electric thawing machine used to bring relief to consumers whose pipes have been frozen. Rates charged for water based on cost of pumping, treatment, distribution, and interest and sinking fund charges.—*Carl Speer, Jr.*

Water Plant Makes Money Selling Power. H. P. Wiedeman. Water Works Eng., **80**: 15, 1127, August 3, 1927. Favorable topographical and hydrological conditions led to construction of a hydro-electric plant as part of new water

works development at Spartanburg, S. C. Small independent hydro-electric plant often uneconomical, especially where stream flow is irregular and marketing and distribution of power costly. Where plant is operated with a water works supply using large portion of the energy without transmission or distribution costs, the initial cost and the cost of operation are reduced. Reinforced concrete dam was constructed across river above series of shoals; water conveyed through 78-inch riveted steel penstock to power house. Filtration plant located near by securing its raw water by gravity through a 24-inch cast iron connection to penstock, discharging filtered water to clear well below filters. Pumps suck water from this well, discharge through a 24-inch cast iron pipe line to a high level reservoir from which water flows by gravity to the city. Ten year contract entered into with local power company for purchase of all power generated in excess of that required at plant. No extra labor required to operate power plant. Operated by filtration plant personnel. Gross returns from operation of power plant consist of (1) power sold, (2) power used, (3) power saved by elimination of low lift pumping. Power plant is operated at a profit.—*Carl Speer, Jr.*

Good Service Calls for Adequate Rates. Robert E. McDonnell. Water Works Eng., **80:** 19, 1335–1336, September 14, 1927. Stresses necessity for increasing water rates as the service is increased and improved. Water plants are becoming more desirable investments for utility operators because of increased efficiency caused by electricity and oil engines. In future, public will demand water of good quality and to produce this municipalities will by necessity be forced to charge rates proportional to improved service. Unless municipally owned plants charge rates great enough to enable them to supply a good water they will open the way for private water holding companies to purchase the property.—*Carl Speer, Jr.*

Using Lead Wire in Making Pipe Joints. W. W. Brush. Water Works Eng., **80:** 19, 1329–1330, September 14, 1927. A 42-inch submerged water supply pipe caulked with lead wool and lead wire. Two strands of lead wool and then two strands of one-quarter inch round lead wire used, alternating wool and wire until joint was flush with the bell. Satisfactory joint obtained with this method.—*Carl Speer, Jr.*

Distribution Pumping Stations of the Metropolitan Water Works. O. A. Doane. Jour. New Eng. W. W. Assoc., **41:** 3, 183, September, 1927. Comprehensive study of sources, conveyances, and pumping stations operating to supply water to Boston and 19 cities and towns. Cross-compound engine found a little more satisfactory than vertical engine. For capacity greater than 20 m.g.d. turbine engine advisable.—*Carl Speer, Jr.*

Concrete-Glass Filter Bottom. F. B. Leopold. Canadian Eng., **52:** 6, 207, February 8, 1927. Illustrated description of a filter bottom, constructed entirely of concrete and glass, installed in a 1,250,000 gallon unit in the plant of the Pennsylvania Water Co., Wilkinsburg, Pa. The cost of installation is somewhat greater than that of the usual filter bottom, but it is believed that

the benefits justify the increased cost. This filter bottom effects saving of at least 12 inch of gravel, and provides an absolute forced even distribution of wash water, which eliminates disturbances in the filter gravel and greatly reduces the possibility of the formation of hard spots in the filter bed. There is, also, no metal to corrode and require renewal.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

Iodization of Public Water Supplies for Prevention of Endemic Goiter. Robert Olesen. Reprint No. 1158, Public Health Reports, 1355, May 20, 1927. The theory that goiter is due principally, if not solely, to a relative or absolute deficiency of iodine is now widely accepted. Goiter prevention and goiter treatment must be sharply distinguished. The minute doses of iodine suitable for prophylactic purposes have little, if any, effect upon existing thyroid enlargements, the sole idea being to maintain the equilibrium of the normal thyroid. Water containing 10 parts of sodium iodide per 1,000,000,000 parts of water is sufficient to prevent goiter but a region is considered to be amply supplied if the water contains half this amount of iodine. The objections to the use of iodized water as a means of preventing endemic goiter are summarized but none are regarded as fundamental: (*a*) the cost is reasonable, being in the neighborhood of one cent per capita per year, (*b*) waste due to the large consumption of water for other than drinking purposes is no more applicable than in the case of purification of the whole water supply (*c*) there appears to be little evidence of any undesirable chemical reaction between iodine and chlorine in the water, (*d*) the taste of the water is not changed, and (*e*) of perhaps greatest importance, the minute quantities of iodine available in iodized drinking water are not considered harmful to any type of goiter. The author's conclusions are that there is considerable doubt as to the ability of iodized water to reduce the incidence of endemic goiter, and although this lack of convincing evidence appears to be the result of poorly controlled experiments rather than any inherent defect in the procedure itself, the iodization of public water supplies, in its present state of development, can not be recommended for widespread adoption.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

Rivers Pollution Prevention with Special Reference to the Work of this Association. J. H. Garner. Pamphlet. Abstract in The Surveyor, **72:** 71, July 22, 1927. This paper is a general review of the stream pollution situation in Great Britain and the various proposals and steps that have been taken for mitigation of pollution. The present conditions obtaining in tidal waters and estuaries, industrial rivers and streams and in non-industrial rivers and streams, are briefly reviewed. Proposals for improvement of these conditions include the survey and classification of streams and watershed areas, the admission of liquid trade wastes to public sewers, the formation of additional River Boards, and provision for increased research in fundamental problems of stream pollution and sewage treatment. The benefits as well as the administrative difficulties of discharging industrial wastes to public sewers and treatment plants are discussed at some length. The advantages of and objections to local River Boards are also presented. The need for coöperative

research in fundamental as well as in local problems is stressed.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

The Disappearance of Typhoid Bacteria in Water. N. L. Wibaut and Isebree Moens. Verslag d. afdeel. Natuurkunde koninkl. akad. v. Wetensch., **36**: 1, 129, 1927. (Dutch) Translation of abstract by E. Reichenow in Zentralblatt fur die Gesamte Hygiene, **15**: 11–12, 486, August 10, 1927. For a study of the reasons for the disappearance of typhoid bacilli in water, water samples from different sources were inoculated with typhoid organisms and stored under similar conditions. The types and numbers of protozoa occurring in the water were also observed. The typhoid bacilli disappeared from tap water, rain water and water from a swimming pool in from seven to ten days and their disappearance corresponded with a marked increase of a bacteria-eating protozoon—oicomonas termo. Cercobodo alexeieffi, Cyclidium glaucoma. With ground water the result was less marked. In one of the experiments the bacilli disappeared only after 4 weeks in spite of the presence of the same protozoa, in another they were not present after 13 days while in water from the same source that had been freed from protozoa by filtration, they remained four days longer. It is concluded that at present unknown factors other than bacteria-eating protozoa are also responsible for the disappearance of the typhoid organisms.—*A. W. Blohm* (*Courtesy U. S. H. P. Eng. Abst.*).

The Bacteria in the Filtered Water in the Case of the Filtration with the Preceding Chlorination. T. Kotoku. Jour. Public Health Assn. of Japan, **3**: 6, 12, June, 1927. Experiments in the City of Osaka frequently showed higher bacterial scores after filtration on water that was first chlorinated than on water filtered but not chlorinated. The author says that this was supposed to be due to incomplete formation of slime on the sand when chlorine is used, consequently allowing percolation of bacteria. Species of bacteria in raw water and in chlorinated and filtered water were isolated and found to be of different types. Thus the bacteria in the filtered water after chlorination were a new type growing in the sand layer of the filter.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Sodium Aluminate as an Adjunct to Alum for the Coagulation of Public Water Supplies. Sheppard T. Powell. Amer. Jour. of Public Health, **17**: 8, 804, August, 1927. Results given are detailed as to methods, analytical data, efficiency of coagulation and costs. The author summarizes as follows: (1) Possible net saving is effected in plant operation due to reduction in alum doses and better plant control; (2) the filtered water is less corrosive due to the lower free CO_2 content; (3) better flocculation in cold water; (4) better agglomeration and more rapid subsidence of the coagulated material; (5) less residual alumina in the filtered water; (6) higher pH values in the filtered water, thereby requiring less lime or soda to raise the reaction to the desired pH for the inhibition of corrosion; (7) possible reduction in subsidence capacities of coagulation and settling basins and reduced mixing periods; (8) longer run between cleaning of filters and reduced wash water as a result of the more efficient coagulation and settling.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Taste and Odor in Sacramento's Water Supply. Ralph A. Stevenson. Western Construction News, 2: 19, 76, October 10, 1927. During the summer months the Sacramento River carries drainage from irrigated lands, particularly about 150,000 acres of rice. The latter is heavily laden with algae. The normal operation of the filtration plant did not satisfactorily remove odors and after experimental work a preliminary chlorine dose of 0.85 to 1.07 p.p.m. was added to raw after water before aeration and the chlorine dose after aeration was reduced from 0.25 to 0.15 p.p.m. The author reports a reduction of algal odors according to Whipple's scale from a value of 4 to a value of 1.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

New Water Filtration Plant at Wenatchee, Washington. Fred J. Sharkey and S. DeMoss. Western Construction News, 2: 19, 56, October 10, 1927. A new 4 m.g.d. rapid sand gravity filter plant has recently been constructed as the first unit of a plan which provides for a normal capacity of 12 m.g.d. The intake in the Columbia River is constructed of reinforced concrete, 39 feet 6 inches long, 16 feet wide at the base and 36 feet high. The intake has inlets at several levels and serves as a sand trap. The sedimentation basin is 70 by 130 by 14 feet deep, divided into two equal compartments with a mixing chamber in each compartment equipped with motor driven agitator. An interesting feature of this basin is that the roof slab was constructed to allow its use for a tennis court. The filter and head house is built over the clear well, the first floor housing switchboard, meters and high-lift pumps; the second, offices, laboratory, dry feed machine room and shops; the third providing chemical storage with a wash water tank 7½ feet deep above. Four 1 m.g.d. filter units are provided. Alum is used for coagulation. The cost totaled $221,500.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Recreational Use of Watersheds. C. G. Gillespie. Western Construction News, 2: 19, 59. October 10, 1927. After reviewing recent events in New Jersey where resort owners and others succeeded in having a bill passed by the legislature legalizing swimming in all waters of New Jersey, the author presents an argument for prompting the reasonable attitude among water works men and recreational users of watersheds.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Absts.*).

The Relation of Endemic Goitre to the Iodine-Content of Soil and Drinking Water. R. McCarrison, C. Newcomb, B. Viswanath and R. V. Norris. Indian Jour. Medical Research, 15: 1, 207, July, 1927. The freedom of localities in ex-Himalayan India is related to conditions other than the iodine content of their soils. Drinking water containing 300 parts of iodine per 100 billion parts of water has not prevented endemic goitre in the presence of a high degree of bacteriological impurity in the water. Bacteriological impurity of a water supply combined with unhygienic conditions of life of the people is stated to be the essential cause of the disease. A deficiency of iodine favors its development. Several methods of determining the iodine content of soils and water are given; also a bibliography.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Paranasal Sinus Infection and Swimming. Frederick E. Hasty. Jour. American Medical Association, **89**: 7, 507, August 13, 1927. It is not considered possible to completely sterilize swimming pools. Filtration and the ultra-violet ray are comparatively satisfactory, but chlorine, in one form or another, has proved one of the most satisfactory chemicals. The water used in the author's studies was taken from pools where one of the above methods was employed and he is unable to determine any difference in the results of either method. The water in a pool during the time of swimming represents the combined washings of the nasal and oral mucous membranes of every swimmer. A number of experiments were made with laboratory animals in an effort to produce paranasal sinus infections. The author's clinical observations are that: (1) the sinus infections resulting from swimming are often severe; (2) children are especially liable to infections; (3) persons who have previously suffered from paranasal infections or nasal obstructions are liable to acute attacks following swimming; (4) the high percentage of infections is due to virulent organisms reaching vulnerable parts of the nose, etc. Attention is called to the fact that man is not an aquatic animal and has a lack of adaptability to aquatic life.—*A. W. Blohm* (*Courtesy U. S. P..H. Eng. Abst.*).

San Fernando Chlorination Plant, Los Angeles. Carl Wilson. Western Construction News, **2**: 19, 73, October 10, 1927. The Los Angeles Water Department has recently completed an automatic chlorination plant treating a maximum flow of 175,000,000 gallons daily. Wallace and Tiernan vacuum automatic machines using pitot tubes instead of venturi tubes are employed. Six machines, each of 150 pounds daily capacity, are used,four feeding a 72 inch trunk and two feeding a 54 inch one. Chlorine is purchased in one ton drums, handled by overhead cranes, and weighed on 5 ton platform scales which are sensitive to ½ pound. The cost of Mission type, tile roofed building was $7500 and the equipment $22,000.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Water Softening in the Home. Edward Bartow. Proc. Iowa Acad. Sci., 33, 165, (1926). From Chemical Abstracts, **21**: 22, 1, 3997, November 20, 1927. "A brief popular discussion of the lime soda process and the base exchange or zeolite process of treating water in the home to improve its condition."—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

South Australian Waterworks and Sewerage Systems. Herbert E. Bellamy. Jour. Royal Sanitary Institute, **57**: 9, 583, March, 1927. The water works for the city of Adelaide, the capital of South Australia, consists of 4 reservoirs of a combined capacity of 7,748 million gallons. The rainfall on 305 square miles of catchment area is utilized and supplies a population of 230,000. The Metropolitan District covers an area of 175 square miles. The length of mains is 1108½ miles. In the year 1878 an act of Parliament was passed, making provision for the necessary expenditure to construct a complete sewerage system for Adelaide. This was the first city in Australia for which a complete sewerage system combined with a sewage farm for the disposal of the sewage was adopted. It is now proposed to abandon the farm

and to construct treatment works of the activated sludge system.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

The Aluminate-Alum Coagulation of Water. C. H. CHRISTMAN. Bulletin 18-A, issued by the Chicago Chemical Company. Alum has been used almost universally as a coagulant in water purification, but its use with certain waters, or under certain conditions has not been satisfactory. The application of hydrogen ion control resulted in great advances, but the principles of colloid chemistry, it is felt, will yield still further advances. Many workers have sought a coagulant that would meet the conditions required by their water supply, and also yield an effluent of sufficient alkalinity to be non-corrosive. Sodium aluminate therefore came into use, but was not entirely satisfactory, until a certain type of the chemical, possessing itself colloidal properties, was used. An account of the results at several plants is given.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

Eliminating Pollution from the Great Lakes and St. Lawrence Waterways—Lake Huron, St. Clair River and Detroit River District. F. GARDNER LEGG. American Jour. of Public Health, **17**: 7, 688, July, 1927. An account is given of the improvements made by communities located on the shores of Lake Huron to protect their water supplies from contamination.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

Coagulation Studies at the Washington Suburban Sanitary District. ROBT. B. MORSE. CARL A. HECHMER, and S. T. POWELL. Ind. Eng. Chem., **20**: 1, 56–59, 1928. Studies were made at two small plants using the same stream as a source of supply. The plants have about a 2 million gallon per day capacity and treat turbities ranging from 5 to 5000 p.p.m. With high turbidities and large alum dosage residual alum was carried into the effluent. Use of sodium aluminate eliminated this condition and gave sufficient alkalinity to produce a floc without the use of sodium carbonate as previously. Using this material it is stated that "better floc formation has been noted over the entire range of turbidities and the reaction is more rapid." Cost of treatment with this method is about the same as for alum.—*Edward S. Hopkins.*

Effect of Salts on the Rate of Coagulation and the Optimum Precipitation of Alum Floc. BEN H. PETERSON and EDWARD BARTOW. Ind. Eng. Chem. **20**: 1, 51–55, 1928. This paper presents very clearly the effect of dissolved salts upon the optimum coagulation point of alum floc. The experiments were made under simulated plant conditions in bottles using a mechanical agitator. After agitation, the floc formed was observed in a darkened room using a Tyndall cone of light. Comparative curves and tables describing the respective effects of sodium sulfate, calcium sulfate, sodium sulfate and sodium carbonate, sodium oxalate, tartaric acid, tannic acid, and potassium phosphate upon isoelectric points are given. It is stated that "one of the major conclusions to be drawn from this investigation seems to be the absolute necessity of some" provision in water works laboratories for producing results relating to floc formation capable of plant duplication. The abnormal behavior of

various salts in relation to the pH value of alum floc precipitation, as shown in the paper, makes it apparent that each water purification plant must determine the conditions of proper control and cannot necessarily be governed by results obtained elsewhere. It is also thought by the authors "that the H ion concentration is less of a controlling factor than the salt content of the water." The paper is of importance and is comparable with that of Theriault and Clark.—*Edward S. Hopkins.*

Problems In Building Large Water Plant. JOHN C. PRITCHARD. Water Works Eng., **80**: 21, 1465, October 12, 1927. In 1929 City of St. Louis, Mo. will dedicate new water works plant located on Missouri River. Heavy increase in water consumption made necessary new plant for which twelve million dollars were appropriated in 1923. Course of water from river to consumer will be as follows: from intake and low service pumps it will pass through Dorr clarifiers 150 feet diameter with detention period of about two hours for preliminary sedimentation with removal of 80 per cent of suspended solids; thence to mixing chambers with detention period 20 minutes, where thorough mixing with lime takes place: on leaving these, sulphate of iron is added and water passes through two more Dorr clarifiers, similar to the first, where coagulation takes place; leaving these with 95 per cent of suspended solids removed, it passes into settling basins with detention period of about 13 hours; then through secondary coagulation basin for dose of alum and then to filter plant, from clear water basin of which it is pumped to the 100-million gallon Stacy Park reservoir about nine miles from plant: from reservoir it flows by gravity to the city. Main channel of Missouri River shifted from south to north bank. Hurdle dikes with necessary revetments were used to bring it back again to south bank. Shore intake, with battered face to river pierced by 15 gates at six different elevations, is divided into five compartments, each with three gates to river and a direct connection to the pump suctions. There will be two low service pumps of 50 million gallons and one of 100 million gallons daily capacity and two 30-million gallon high service pumps, pumping against about 325 feet head; all of steam turbine driven centrifugal type. Four boilers of 650 h.p. each with necessary stokers, coal and ash handling machinery, air preheaters etc. will be used. Reservoir at Stacy Park is a concrete structure 600 by 800 feet by about 30 feet deep. Footings are on a stiff yellow clay, with a cut-off wall of sheet piling to shale about 14 feet down. Main walls are buttressed every 10 feet. It is to be covered, roof being supported on some 1700 columns. The filter plant contains 20 filters, of a rated capacity of 4 million gallons per day each from the 1400 square feet filter area of a 28-by 50-feet sand bed. Strainer system is a pipe manifold, with cast iron laterals, one foot centers.—*Carl Speer, Jr.*

A New Purification Plant With Some Unusual Features. WYNKOOP KIERSTED. Water Works Eng., **80**: 21, 1478, October 12, 1927. Storage reservoir at Ft. Collins, Col. plant completely remodeled and now serves as settling basin with novel feature of adjustable weir gates. Gates are made adjustable because fluctuation of river level causes several feet variation in the operating level of water in the basin. Six filter units provided each having an area of

280 square feet and a rated capacity of one million gallons daily. The six-inch rewash pipe discharges into the main wash water trough of each filter instead of into the filter drain pipe. Purpose is to waste filtered water from a filter immediately after washing for a period of 5 to 15 minutes, until the filter settles down to normal working conditions.—*Carl Speer, Jr.*

Elevated Tank Checks Pressure Variations. JAMES E. GIBSON. Water Works Eng., **80**: 21, 1467, October 12, 1927. Peak demands, occurring suddenly and causing severe drops in pressure and excessive loads on the pumping machinery, caused the city of Charleston, S. C., to construct a large storage tank near the center of the distribution system. Observations showed that a storage of one and one-half million gallons at an elevation of 120 feet would be necessary for uniform pressure in the city and uniform rate and pressure at pumping stations. Overflow trough, considered a unique feature, is 18 inches wide and 18 inches deep and is constructed on outside edge of the tank. Total weight of tank when full, including foundations, is 22,120,000 pounds. Tank has been in service one and one-half years. Since its installation it has been possible to maintain uniform pumping rate at the pumping stations with uniform pressure throughout the 24 hours.—*Carl Speer, Jr.*

St. Paul Eliminates Odors And Taste by Aëration. R. A. THUMA. Water Works Eng., **80**: 21, 1476, October 12, 1927. At St. Paul, Minn., plant, water is given brief violent aëration. Air forced through water in small sprays under pressure of 5 to 6 pounds per square inch increases oxygen content 6 per cent and removes odors. Application of air is at rate of 6000 cubic feet per million gallons of water. Corrosiveness of water is increased when oxygen is added. Cost of aëration by compressor method, including interest on investment and operation, amounts to about 50 cents per million gallons.—*Carl Speer, Jr.*

Reliability Features Of An Electrically—Operated Pumping Station. R. C. DENNETT and GEORGE L. SWAN. Jour. of New Engl. Water Works Association, **41**: 3, 268–278, September, 1927. Even with improved modern equipment provision should be made to take care of possible interruption of electric current supply. Two methods suggested to overcome hazard of interruption of service; (1) elevated storage for supply to distribution lines of water system; (2) sufficient reserve units which will not be susceptible to interruption of supply of electric current. The former is more dependable. Storage recommended: reservoirs on tops of hills, stand-pipes, elevated tanks. For the latter a gasoline-driven pumping unit recommended as stand-by equipment.—*Carl Speer, Jr.*

How Water Works Men Can Prevent Fires. O. W. MOWRY. Water Works Eng., **80**: 22, 1537, October 26, 1927. Automatic sprinklers reduce losses from fire by quickly extinguishing those that cannot be prevented. Reliable water supply must be available at all times. Sprinkler valves must be kept open and regular inspection is necessary to insure this. Pipes and pump impellers must be kept clear of foreign articles likely to obstruct water flow. Experi-

ences of fire outbreaks at times when service at pumping station was interrupted show necessity of a secondary water supply.—*Carl Speer, Jr.*

Water Works Advertising With A Punch. R. H. Cory. Water Works Eng., **80**: 24, 1669, November 23, 1927. Water works officials desire publicity; but, because so many of the water works are municipally owned, they have not the funds to spend. A water utility has nothing to sell but water; it should impress the people that they need the best water and best service obtainable. Advertising should educate the public to reduce the enormous waste of water, gain confidence of users, create an interest in the local supply, make the public realize that rates must be sufficient to meet expenses of upkeep and reserve, and that the problem of a good water supply affects them and the future of the community. Samples of short titles and short articles are given.—*Carl Speer, Jr.*

Pure Water? Then Adequate Rates. Robert E. McDonnell. Water Works Eng., **80**: 23, 1607, November 9, 1927. Several examples cited where cities are spending large sums to give consumers pure water. Dangers from water bacteria well-known and must be avoided. In several instances the municipality has been held liable for sickness or death traced to use of impure water supply. To maintain high standard of water quality, rates charged the consumer must be sufficient to cover cost of maintaining the necessary skilled personnel. Inadequate rates, curtailing funds necessary for operation, tend to lower high standards for water supplies.—*Carl Speer, Jr.*

Water Works Service Versus a River in Flood. The American City, **37**: 5, November, 1927. A dramatic account of the many difficulties confronting the officials of the Arkansas Water Company of Little Rock in continuing uninterrupted service during the period of the great flood of 1927. From April 19 until April 22, under the most trying conditions, nearly 1000 men, including 150 convicts, labored to increase the height of the levee surrounding the pumping station and in operating the boilers and pumps. The passing of the flood crest on April 22 relieved the situation.—*C. R. Cox.*

Public Water Supplies in Colorado. Dana E. Kepner. The American City, **37**: 5, November, 1927. Statistics are given of 200 public water supplies in Colorado of which 194 are municipally owned. One hundred and five supplies are from surface sources, 80 from ground water sources, and 15 from combined sources. Infiltration galleries are used in seven surface supplies; storage is the only treatment in 26 other surface supplies; and filtration plants are provided at 24 places. The supply of one municipality is softened. Chlorination alone is provided for 29 surface supplies and one ground water supply. Three municipalities have dual supplies, one for potable and culinary purposes and the other for sanitation, irrigation, and fire protection purposes. Artesian wells on most private properties provide an adequate public water supply for Monte Vista. The State Board of Health approves of supplies furnishing water the quality of which meets the United States Treasury Department Standard for potable waters used in interstate traffic. Munici-

palities are permitted to use highway signs indicating this approval.—*C. R. Cox.*

"The Cash Value of Pure Water." R. E. McDonnell. The American City, **38**: 1, 171–172, January, 1928. "An investment for pure water will invariably bring good, safe returns . . . . in health, happiness, comfort, or added income." San Francisco is spending $300,000,000; Sacramento, $12,000,000, or $120 per capita; and Los Angeles is preparing to spend very large sums to secure water from the Colorado river. Smaller municipalities also have made large per capita expenditures. The quality of the water has greatly improved as a consequence and the marked reduction in the extent of water-borne disease is the invaluable result. So certain is this result that courts are holding that municipalities are responsible for deaths from water-borne disease when suitable steps are not taken to furnish a pure and wholesome water. Pure water is delivered to many municipalities, but physically attractive water unfortunately is not as common as many believe. The extent of spring water sales in many cities testifies to this fact. It is estimated, for instance, that $12,000,000 are spent per year for spring water in Chicago alone. The art of water purification has progressed to a point where water of satisfactory quality may be produced provided one is willing to meet the expense.—*C. R. Cox.*

Analysis of Arch Dams by the Trial Load Method. C. H. Howell and A. C. Jaquith. Proc. Am. Soc. Civ. Eng., **54**: 1, 61–95, January, 1928. The authors present a method of arch dam analysis that has been developed in the Designing Office of the United States Bureau of Reclamation. It is based on the assumption that an arch dam is composed of systems of horizontal arches and vertical cantilevers, that each system carries a proportion of the total load, and that the deflections of the two systems are equal. When a proportionate loading has been found that gives equal deflections at all points for both systems, the stresses are computed and are considered to be those which will obtain in the dam. Sixteen illustrations and 50 equations are given.—*John R. Baylis.*

Stream Flow in General Terms. M. D. Casler. Proc. Am. Soc. Civ. Eng., **54**: 1, 97–122, January, 1928. A general method for the analysis of stream flow in irregular channels is given. The Chezy formula is not properly applicable to such cases. The discussion is confined to rectangular channels the width of which is uniform and so great in comparison with the depth that the hydraulic radius may be considered equal to the depth. Sixty equations are given.—*John R. Baylis.*

The Effect of Agricultural Drainage upon Flood Run-Off. S. M. Woodward and F. A. Nagler. Proc. Am. Soc. Civ. Eng., **54**: 1, 165–83, January, 1928. A survey of stream-flow conditions prior and subsequent to extensive drainage was made upon the Des Moines and Iowa Rivers. The records of these two streams show that during flood periods there has been no significant change in their behavior which may be attributed to drainage. The total run-

off from storms of like precipitation, the maximum rates of discharge, and the rain-water storage conditions within the basins seem to have been unaltered by the extensive drainage operations. It appears that agricultural drainage has had negligible effect upon the magnitude of the Mississippi River floods.—*John R. Baylis.*

ABSTRACTS, SUB-COMMITTEE NO. 9

Joint Research Committee on Boiler Feedwater Studies

The Behaviour of Boiler Plates at High Temperatures. A. Pomp. Iron and Coal Trades Rev., **116**: 3125, January 20, 1928, p. 74. First part of investigations deals with characteristics of boiler plates at high temperatures; second part deals with susceptibility of boiler plates to aging. Abstract of paper entitled **"Aging and Recrystallisation; the Behaviour of Boiler Materials at High Temperatures,"** read before Congress for Testing Materials, Berlin.

Failures of Boiler Tubes Traceable to Segregated Metal. Power, **67**: 6, February 7, 1928, p. 250. Gives chemical composition of material machined from inner and outer zones of steel tubes of badly segregated metals; experiments were made in order to determine extent to which pitting and general corrosion in tubes could be ascribed to segregated ingot material.

Essay on "Marine Evaporators." Inst. Mar. Engrs.—Trans., January 1928, pp. 718–722. Need for pure fresh water at sea is of two fold order; for fresh-water-supply purposes and for boiler feeding; principle on which evaporator functions; evaporator design; operation; cleaning evaporator.

Boiler Feed Water. A. G. Elliott. Pacific Mar. Rev., **25**: 1, January 1928, pp. 20–22. How to test boiler water for acidity or alkalinity; chemical solutions and apparatus required; chemical analysis of waters in various ports of world, viz., San Francisco, Gatun Lake, Valparaiso, River Plate; Buenos Aires, Amazon River, Kobe, New York, Philadelphia, and Baltimore.

Electrometric Equipment. Gas Engr., **44**: 621, January 1928, p. 21. Hydrogen-ion control of boiler feedwater is recent interesting development; example of automatic control of this kind is to be found in power station of Public Service Gas and Electric Company, at Perth Amboy, N. J., where system is used to regulate addition of caustic soda and sodium phosphate to boiler feedwater, and to keep latter at constant ionization.

Degassing Water. Jacobus, D. S. U. S. 1,650,129, Nov. 22. Chem. Abstracts, February 10, 1928, **22**: 473. H_2O for use in boilers or other purposes is first boiled under reduced pressure and then passed over oxidizable material such as Fe.

What is Important in the Examination and Estimation of Boiler-Feed Waters for Heavy-Duty Boilers? Haupt. Chem.-*Z*tg., **51**: 943–5, 1927, Chemical Abstracts, February 20, 1928, **22**: 655. A critical study of the factors of per-

formance of boilers shows that the usual estimation of boiler-feed water is not sufficient. Among the other factors to be considered are the pretreatment of the water, the nature of the condensate, and the water capacity of the boiler. The modern practice in control of alkalinity and other factors in corrosion renders closer study of the actual conditions in each step necessary. The methods of pretreating the water are reviewed and criticized and the check made possible through the condensate is pointed out.—*J. N. Wickert.*

Apparatus for Purifying Feedwater for Locomotive Boilers, etc. WAGNER, FRITZ. U. S. reissue 16,786, Nov. 22. (Original patent No. 1,474,218 was granted November 13, 1923). Chem. Abstracts, February 10, 1928, 22: 473.

Boiler Water Treatment at the Sons of Gwalia, Ltd., Western Australia. EDQUIST, V. T. Bull. Inst. Mining Met., 279: 2–8, 1927; Chem. Eng. Mining Rev., 20: 43–45, 1928. Chem. Abstracts, February 20, 1928, 22: 655. Water from wells contg. NaCl. 70.82, $MgCl_2$ 33.03, $CaCl_2$ 26.98, $CaCO_3$ 11.57, $CaSO_4$ 22.71 formed scale and was intensely corrosive. Treatment by the hot caustic soda process was unsatisfactory. Treatment by CaO and $BaCO_3$ (crude witherite) was adopted. Witherite is ground with the lime and agitated in tanks with the water for 24 hrs. The treated water has given satisfaction for 3 years.—*E. B.*

Practical Boiler-Feedwater Treatment (Beitraege zur praktischen Speisewasserpflege), Zeit. des Bayerischen Revisions-Vereins, 31: 24, December 31, 1927, pp. 265–268. Requisites of chemically pure water; water from process steam; boiler water; experience shows that boiler plate is most resistant to corrosion when feedwater contains a certain amount of soda or sodium-hydroxide; effect of silicic acid on feedwater; rules for regular inspection of feedwater. Bibliography. (Concluded from December 24, 1927.)

Pretreatment of Boiler Feedwater (L'épuration préalable de l'eau d'alimentation des générateurs). J. GUTH. Assns. Françaises de Propriétaires d'Appareils à Vapeur—bul., 8: 30, October, 1927, pp. 299–315, 1 fig. Treats of physico-chemical purification from theoretical point of view and its applications and chemical purification; purification by soda and heat and by continuous cleansing; interpretation of results. (Concluded.)

Treating Water for Steam Boilers, etc. BAKER, G. O. Brit. 266,280, February 20, 1926. Chem. Abstracts, February 10, 1928, 22: 473. H_2O is passed through a circular raceway in contact with abradable balls. The balls and the raceway itself may be formed of graphitic cast Fe, or the balls may comprise other metals such as Al and Zn, and S also may be used as a binder. An apparatus is described.

The Willans-Luard System. Locomotive Superheating and Feed Water Heating (supp. to Locomotive, January 14, 1928), pp. 132–138, 9 figs. System makes use of exhaust steam, exhaust flue gases, and live steam which would be wasted at safety valves.

Corrosion in Steam Heating Systems. F. N. Speller. Am. Soc. Heating and Ventilating Engrs.—Jl., **34**: 2, February 1928, pp. 117-124, 4 figs. Review of corrosion problem in steam-heating system, treatment of boiler feedwater to correct corrosion, and rules to observe for its prevention in high and low-pressure systems.

Steam at High Temperatures. M. Staeger and P. Bohnenblust. Metallurgist (supp. to Engineer), January 27, 1928, p. 15. Relates mainly to feedwater, but main question attacked is that of oxidation of steel by hot water and steam, and two possible directions in which attack on steel may occur are discussed; first relates to presence of dissolved free oxygen in boiler water; second is that due to direct reaction between hot steam, or water and iron, resulting in formation of iron oxide and free hydrogen. Abstract translated from B. B. C. Mitteilungen, November, 1927.

Volumetric Determination of Sulphates in Waters by Bahrdt's Method (ueber die volumetrische Bestimmung von Sulfaten im Wasser nach Bahrdt). M. Kehren and H. Stommel. Chemiker-Zeitung, **51**: 94, November 26, 1927, pp. 913-915 and 934-935 (**51**: 96). Tests on volumetric method of determining sulphates in water by filtration through permutit followed by titration with potassium palmitate have shown that for hard waters at least 100 grams of permutit must be used, and rate of filtration should not exceed about 400 cc. per hour.

Chemical and Physico-Chemical Purification of Industrial Waters (Épuration Chimique et Physico-Chimique des Eaux Industrielles). Langumier. Arts et Métiers, **80**: 87, December 1927, pp. 458-467, 2 figs. Treats of methods of purifying water by soluble salts, by "vaccination," by change of base and employment of zeolites; methods of physical purification by steam of by use of detarring apparatus; mixed physico-chemical methods; oil removal from condensed steam.

Natural and Artificial "Black Sand" for Manganese Removal from Water (Natuerlicher und kuenstlicher schwarzer Sand als Entmanganungsmaterial fuer Wasser). Luehrig. Gas- und Wasserfach, **70**: 53, December 31, 1927, pp. 1277-1281. Report from chemical research bureau of city of Breslau on origin and nature of manganese in water and use of brown or black filter sands, whose particles are coated with oxide compounds of manganese, for removal of manganese from water; details of experiments in which natural "black sand" from old filters or artificially synthesized "black sand" was used.

Developments in Water Softening Practice. C. P. Hoover. Water Works, **67**: 1, January, 1928, pp. 40-42. Elevating chemicals to storage bins; applying chemicals to water; mixing tanks and agitating devices; Dorr clarifiers; methods for further reducing hardness; lime-softened water not stable; fuels for CO_2 production; recarbonating lime-softened water; addition cf aluminum salts.

Zeolite Process of Water Softening. A. S. Behrman. Water Works, **67**: 1, January, 1928, pp. 26–28, 3 figs. First application of zeolites to water softening; introduction of New Jersey greensand as softening medium; nature of synthetic "gel;" softening capacity between regenerations; frequency of regeneration; water consumption for regeneration; softening rates; loss of head: adaptability; "porosity;" gel-type zeolite water softening fulfils demands for greater softening capacity, extremely high rates of exchange, and economy in maintenance and operation.

An Unusual Water Works. W. Rudolfs. Water Works, **67**: 1, January 1928, pp. 7–8, 5 figs. Water treatment plant at Phillips' glow-lamp works at Eindhoven, Holland; only small quantities of CO_2 traces of iron and no manganese can be tolerated; capacity of plant 264,000 gallons per hour; for removal of carbon dioxide water is aerated in six separate aeration units; filter beds, filled 8 feet deep with crushed lava; filters cleaned by applying air under pressure from bottom, followed by wash water and mixture of air and water; cost of treatment.

Recent Developments in Water Treatment and Filtration. J. R. Baylis. Water Works, **67**: 1, January 1928, pp. 37–39. Type of treatment no longer influenced by public opinion; water of certain chemical balance most suitable for domestic uses; optimum conditions for coagulating water; mixing basins; settling basins; rapid sand filters; instruments to aid filter operator; aeration; excess lime treatment and recarbonation.

Stratigraphy and Geologic Structure of Northern Illinois. F. T. Thwaites. Ill. State Geol. Survey—Report of Investigations, **13**: 1927, 49 pp. 4 figs. partly on supp. plates. Potable underground waters can be obtained in quantity throughout northern Illinois; they form important resource which is utilized by many industries, cities, villages, and individuals; Rockford is largest city in Northern Illinois to use well water for its public supply; present paper is designed primarily as aid to engineers and well drillers.